MOSQUITO INTERCEPTIONS AND RELATED PROBLEMS IN AERIAL TRAFFIC ARRIVING IN THE UNITED STATES

JOHN H. HUGHES [1]

The problem of preventing importation of live mosquitoes and other medically important arthropods into the United States was relatively simple 30 years ago. At that time, approximately 5,000 aircraft were arriving annually in Public Health Service quarantine. The aircraft in use then were rather small and often flew from countries no more distant than the Americas. Most of them could be met at the time of arrival, inspected, and treated to eliminate any live mosquitoes.

Beginning in 1943 the annual rate of foreign flights increased rapidly. Aircraft arriving in Public Health quarantine totaled 36,322 in 1945, increased to 54,759 in 1955, and reached 70,383 in 1960. As the number of flights increased, the size and speed of aircraft and the distance covered in non-stop flights kept pace, thus adding to the complexity of the insect control problem. It is not unusual for an aircraft en route from Africa, South America, or elsewhere in the world to arrive at one of our ports in the South, in Puerto Rico, or in Honolulu in a matter of a few hours, thus bringing us very close to important arthropod vectors of other parts of the world and to the diseases they transmit. The protective barrier of time and distance provided by the earlier, slower aerial traffic has been removed and mosquitoes and other insects may now arrive alive from virtually all parts of the world.

Another of the growing problems facing those responsible for the control of insects transported accidentally in aircraft is that of insecticide resistance. Numerous species of medically important insects have exhibited varying and sometimes alarming degrees of such resistance. A list prepared by the World Health Organization (1) in late 1960 shows that the insects known to be resistant to chlorinated hydrocarbons ordinarily employed in malaria eradication programs include 30 species of anopheline mosquitoes, many of importance as malaria transmitters. At least four of these (*A. albimanus, A. pseudopunctipennis, A. punctimacula,* and *A. quadrimaculatus*) have been intercepted on aircraft arriving in the United States during the past few years.

PROTECTIVE MEASURES. The Public Health Service quarantine entomology program is directed against the hazard of introduction and establishment of insects, particularly vectors of diseases affecting man. Professional entomologists and supporting staff are maintained in principal locations where the threat of insect importation is considered greatest. Quarantine stations apply insect control measures in aircraft upon arrival from foreign countries as required by quarantine regulations authorized by the Public Health Service Act. The entomology program involving aerial traffic includes aircraft disinfestation and entomological surveillance of airports. This is supplemented with *Aedes aegypti* control activities in many of the international traffic points in the yellow-fever receptive area of the South, Puerto Rico, and the Virgin Islands (2).

In general, aircraft arriving in the United States from foreign countries located in the area bounded on the north by 45 degrees north latitude and on the south by 45 degrees south latitude are subject to disinfestation measures. Planes arriving in this country at points south of the 35th parallel are subject to disinfestation on a year-round basis. Aircraft arriving north of the 35th parallel are subject to disinfestation only during the period April

[1] Scientist Director, Division of Foreign Quarantine, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C.

through September, except under special circumstances which may arise.

Approximately 50 percent of all arriving aircraft are considered of significance to the entomology program and are inspected for presence of insects. Results of these on-arrival inspections will be mentioned later in this paper.

AIRCRAFT DISINFESTATION. Insecticidal aerosols formulated for use in aircraft disinfestation are employed. Four formulations, known as G-382, G-651, G-1152, and G-1029, each containing pyrethrins and DDT, are authorized by the Public Health Service (3) and the World Health Organization (4) for use on aircraft in international traffic. A minimum application of five grams of these insecticidal aerosols is recommended by the Public Health Service for each 1,000 cubic feet of enclosed aircraft space to be treated. The World Health Organization currently recommends a minimum of 10 grams for each 1,000 cubic feet of enclosed space. Also, that Organization insists on application of the insecticide prior to departure of aircraft from an airport, while the United States and other countries provide for disinfestation of aircraft while in flight if not accomplished prior to takeoff. However, we are now studying the feasibility of using the predeparture application of an insecticide on aircraft leaving this country. Such application should give greater protection against insects that are transported by aircraft. It would (1) permit the use of a single, large application of insecticide which could be employed in the absence of passengers and crew; this, perhaps, would meet both public health and agricultural requirements; it would (2) immobilize insects at the beginning of a flight and provide a longer interval during which the slow-acting DDT or other insecticides could take effect; and (3), when applied to aircraft departing for the United States, would eliminate the need for the on-arrival disinfestation now applied to more than 15,000 aircraft arriving each year. This method could be employed only with the full cooperation of health departments of other countries to protect the United States against an influx of live insects.

The predeparture disinfestation concept is not new. The United States for many years has been an advocate of predeparture spraying of aircraft, provided proper conditions prevail. As early as 1939 the Service established and operated an experimental aircraft disinfestation base at Trinidad, B.W.I., with an inspection station at San Juan, P. R. (5). This work was expanded and continued until 1941 when the quarantine inspectors were recalled and the responsibility was transferred to the airlines where it soon met with abandonment in favor of in-flight application. Since 1941 the Service has applied predeparture measures in a few instances when requested by other countries.

Methods other than the use of insecticidal aerosols are being considered for use in international air traffic. These include vaporization of insecticides and the use of single-dose aerosol dispensers of a semi-automatic nature.

ENTOMOLOGICAL FINDINGS. Thousands of insects, nearly all in the adult stage, are found on aircraft arriving at our ports from foreign countries each year. An earlier report by the writer (6) covered entomological records for aircraft arriving in the United States during the 10-year[2] period ending June 30, 1947. The present paper is for the 13-year period ending June 30, 1960, and is concerned primarily with mosquitoes. The records are from quarantine stations located at Brownsville and Houston, Texas; Honolulu, Hawaii; Miami, Florida; New Orleans, Louisiana; New York, New York; and San Juan, Puerto Rico. These seven localities receive most of the international flights arriving in this country.

During the 13-year period beginning July 1, 1947, and ending June 30, 1960, nearly a quarter of a million insects were recovered from aircraft. This number is shown in Table 1 which includes other

[2] Fiscal year, which is 12-month period ending June 30, employed throughout paper.

TABLE 1.—Aircraft disinfestation data, July 1, 1948–June 30, 1960[1]

Fiscal year	Number of aircraft			Entomological findings							
		Harboring		All Insects				Mosquitoes			
	Inspected	All insects	Mosquitoes	K-d	Alive	Dead	Total	K-d	Alive	Dead	Total
1960	37,248	8,394	1,609	3,007	3,213	25,435	31,655	359	197	5,896	6,452
1959	37,245	7,591	959	4,872	3,849	19,555	28,276	269	326	1,220	1,815
1958	31,192	6,346	785	3,598	2,832	16,919	23,349	138	257	1,093	1,488
1957	30,145	4,467	728	2,325	2,712	9,878	14,915	113	333	1,403	1,849
1956	28,250	4,879	829	3,028	3,505	9,849	16,382	154	522	1,421	2,097
1955	31,412	4,209	474	3,123	2,973	6,602	12,698	81	221	471	773
1954	28,563	4,601	388	3,449	3,129	7,797	14,375	59	124	414	597
1953	20,407	3,645	299	2,521	2,625	6,719	11,865	62	75	358	495
1952	23,677	5,283	358	5,869	2,445	12,215	20,529	48	45	406	499
1951	22,668	4,030	496	3,450	3,035	13,470	19,955	200	73	606	879
1950	23,421	4,772	670	2,225	4,036	13,724	19,985	155	83	1,202	1,440
1949	23,531	4,053	695	1,135	1,898	11,374	14,407	86	85	1,044	1,215
1948	21,751	4,445	629	973	1,136	18,772	20,881	25	127	941	1,093
Total	359,510	66,715	8,919	39,575	37,388	172,309	249,272	1,749	2,468	16,475	20,692

[1] Brownsville, Honolulu, Houston, Miami, New Orleans, New York, and San Juan (except Honolulu not included in 1948, 1949, and 1950.

TABLE 2.—Mosquitoes found in aircraft[1] during the 13-year period ending June 30, 1960

Mosquito species	Condition when found: Knock-down	Alive	Dead	Total
Aedeomyia catasticta Knab	0	0	1	1
Aedeomyia squamipennis (L.-A.)	0	1	9	10
Aedes aegypti (L.)	1	8	9	18
Aedes albifasciatus (Macq.)	1	0	137	138
Aedes albopictus (Skuse)	0	0	1	1
Aedes atlanticus D. and K.	0	0	1	1
Aedes cantator (Coq.)	0	0	1	1
Aedes condolescens D. and K.	0	0	1	1
Aedes dorsalis (Meig.)	0	0	7	7
Aedes euiris Dyar	1	0	17	18
Aedes euplocamus D. and K.	0	0	2	2
Aedes fulvithorax (Lutz)	0	0	2	2
Aedes lineatopennis (Lud.)	0	0	7	7
Aedes mediovittatus (Coq.)	1	0	2	3
Aedes mitchellae (Dyar)	0	0	3	3
Aedes nigromaculis (Lud.)	1	0	0	1
Aedes obturbator D. and K.	0	0	1	1
Aedes pampangensis (Lud.)	0	0	1	1
Aedes polynesiensis Marks	0	0	3	3
Aedes scapularis (Rond.)	0	1	4	5
Aedes serratus (Theob.)	0	0	1	1
Aedes sollicitans (Walk.)	12	12	256	280
Aedes species	12	25	1,526	1,563
Aedes sticticus (Meig.)	0	0	1	1
Aedes taeniorhynchus (Wied.)	338	204	4,474	5,016
Aedes thelcter Dyar	0	2	5	7
Aedes tortilis (Theob.)	0	3	13	16
Aedes vexans (Meig.)	0	1	25	26
Aedes vexans nipponii (Theob.)	0	0	2	2
Aedes vexans nocturnus (Theob.)	0	0	16	16
Aedes vigilax (Skuse)	0	0	3	3
Anopheles albimanus Wied.	25	69	144	238
Anopheles albitarsis L.-A.	0	0	23	23
Anopheles annularis V.d.W.	0	0	3	3
Anopheles annulipes Walk.	0	0	1	1
Anopheles atropos D. and K.	0	1	4	5
Anopheles barbirostris V.d.W.	0	0	2	2
Anopheles crucians Wied.	17	5	145	167
Anopheles grabhamii Theob.	0	1	30	31
Anopheles litoralis King	0	0	4	4
Anopheles neomaculipalpus Curry	0	1	5	6
Anopheles nigerrimus Giles	0	0	4	4
Anopheles pseudopunctipennis Theob.	0	0	9	9
Anopheles punctimacula D. and K.	0	0	3	3
Anopheles punctipennis (Say)	0	0	1	1
Anopheles quadrimaculatus Say	10	6	140	156
Anopheles sinensis Wied.	0	0	3	3
Anopheles species	4	7	262	273
Anopheles subpictus Grassi	0	0	2	2
An. subpictus indefinitus (Lud.)	0	0	40	40
Anopheles vestitipennis D. and K.	0	3	7	10
Anopheles walkeri Theob.	6	0	5	11
Culex americanus (N.-L.)	0	0	3	3
Culex annulirostris Skuse	0	0	22	22
Culex bahamensis D. and K.	2	0	21	23

[1] Which arrived at Brownsville, Honolulu, Houston, Miami, New Orleans, New York and San Juan (except Honolulu not included in 1948, 1949, and 1950).

TABLE 2.—(Continued)

Mosquito species	Condition when found			Total
	Knock-down	Alive	Dead	
Culex coronator D. and K.	0	0	1	1
Culex duplicator D. and K.	0	0	1	1
Culex erraticus (D. and K.)	0	0	4	4
Culex fuscocephalus Theob.	0	0	4	4
Culex habilitator D. and K.	0	0	58	58
Culex interrogator D. and K.	0	0	1	1
Culex nigripalpus Theob.	13	30	129	172
Culex peus Speiser	1	4	18	23
Culex pilosus (D. and K.)	0	0	2	2
Culex pipiens L.	1	2	47	50
Culex quinquefasciatus Say	754	1,362	2,680	4,796
Culex salinarius Coq.	38	9	245	292
Culex sitiens Wied.	0	0	8	8
Culex species	354	434	2,911	3,699
Culex tarsalis Coq.	21	61	257	339
Culex tritaeniorhynchus Giles	0	0	6	6
Culex univittatus Theob.	0	0	1	1
Culex whitmorei (Giles)	0	0	65	65
Culiseta annulata (Schrank)	0	0	1	1
Culiseta inornata (Will.)	1	3	13	17
Culiseta particeps (Adams)	0	0	1	1
Culiseta species	8	5	25	38
Deinocerites cancer Theob.	2	0	35	37
Mansonia crassipes (V.d.W.)	0	0	1	1
Mansonia dives (Schiner)	0	0	2	2
Mansonia flaveola (Coq.)	1	0	9	10
Mansonia humeralis D. and K.	2	0	10	12
Mansonia indubitans D. and S.	3	9	168	180
Mansonia perturbans (Walk.)	4	1	26	31
Mansonia pseudotitillans (Theob.)	0	0	1	1
Mansonia species	16	7	347	370
Mansonia titillans (Walk.)	20	47	295	362
Mansonia uniformis (Theob.)	0	0	10	10
Orthopodomyia signifera (Coq.)	0	0	1	1
Psorophora ciliata (Fab.)	7	4	42	53
Psorophora confinnis (L.-A.)	51	93	741	885
Psorophora cyanescens (Coq.)	3	12	28	43
Psorophora discolor (Coq.)	2	4	11	17
Psorophora pygmaea (Theob.)	0	0	37	37
Psorophora species	2	3	169	174
Uranotaenia lowii Theob.	0	1	19	20
Uranotaenia sapphirina (O.S.)	0	0	8	8
Wycomyia species	0	4	0	4
Culicidae species	14	23	623	660
Total	1,749	2,468	16,475	20,692

data relating to aircraft treatment as accomplished on an annual basis. Of this number, 15.9 percent were knocked down (alive, but inactive), 15.0 percent were alive (active), and 69.1 percent were dead. Although not shown in the table, the yearly average of all insects intercepted at the seven points mentioned was 19,175.

Because of heavy aircraft schedules and sometimes lack of adequate personnel, it is often possible to make only a rapid inspection of an aircraft following the on-arrival insecticide application. Even then, the results are interesting, particularly with reference to mosquitoes. For example, 20,692 mosquitoes (2,468 alive, 1,749 knocked down, and 16,475 dead) were intercepted during the 13-year period, as may be noted in Table 1. This large number is also shown in Table 2 which lists all of the mosquitoes by species, viable condition when found, and number. The family Culicidae is represented here by 11 genera and 92 species. The important malaria-transmitting genus *Anopheles* alone comprises 20 species, or 21.7 percent of all species found. This is surpassed only by *Aedes* which comprises 28 of the total species. The work of Stone, *et al.* (7) was used as a basis in arriving at the taxonomic listings in this paper, except for *C. quinquefasciatus* which is considered as a species.

More than 80 percent (80.8) of the mosquitoes intercepted during the 13-year period belong in two genera, *Aedes,* (34.5 percent) and *Culex* (46.3 percent). *Aedes taeniorhynchus* alone was represented by 5,016 specimens and comprised 70.2 percent of all the *Aedes* and 24.2 percent of all the mosquitoes. *Culex quinquefasciatus* likewise consisted of a large number of specimens. The two species collectively consisted of 9,812 specimens or 47.4 percent of all mosquitoes found.

Fifty-one species of mosquitoes shown in Table 2 are not known by the writer to be present in nature in one or more of the general areas (Continental United States, Hawaii, and Puerto Rico) where they were intercepted on aircraft during the 13-year period considered. The finding of these mosquitoes is proof that they are being transported to this country, sometimes from distant airports. The areas of interception of these 51 non-indigenous species are shown in Table 3. Twenty-nine of these species apparently are new to our aircraft interception records for the areas considered. The remaining 22 species of Table 3 were also reported in an earlier paper (6).

Twenty of the species shown in Table 3, intercepted at ports in Continental United States, do not occur in this country. Of these 20 species, *Anopheles grabhamii, Anopheles neomaculipalpus,* and *Anopheles vestitipennis* were represented by specimens which were alive when found on aircraft. Five species included specimens in a knocked-down condition when first observed.

Honolulu interceptions included 31 species of mosquitoes non-indigenous to the Islands of Hawaii. Noteworthy among this array are eight species of anophelines. Although all but one of the specimens were dead when the aircraft were inspected upon arrival at Honolulu, the real hazard of introduction of some of these species is apparent. In view of the semitropical climate in Hawaii and the presence of only three species established in nature there, it is important that mosquito control measures be applied effectively on aircraft entering that State.

Records indicate that Puerto Rico was more fortunate than Continental United States and Hawaii with respect to receiving non-indigenous mosquitoes in aerial traffic. Only two such species were recorded for aircraft arriving in San Juan during the 13-year period.

Thirty-seven of the species listed in Table 3 (each preceded by an asterisk) apparently have not been reported as being found under natural conditions in Continental United States, Hawaii, and Puerto Rico.

In addition to the non-indigenous mosquito species it is not uncommon to find other species of Culicidae on aircraft arriving at various airports in the United States where they are not known to occur in nature, although they may be present in other parts of the country. Some species transported from other countries to our airports are not actually considered as being imported since the species also occur in the airport area where the aircraft interceptions are made.

The interception of the large number of non-indigenous species mentioned leaves little doubt as to the value of quarantine measures against the importation of insects. The escape and establishment of any one of the more important malaria

TABLE 3.—Mosquitoes intercepted on aircraft which arrived in areas where the species are not known to occur, July 1, 1948–June 30, 1960

Mosquito species	Place and number of specimens intercepted			
	Continental United States	Hawaii	Puerto Rico	All stations
n*Aedeomyia catasticta Knab	..	1	..	1
*Aedeomyia squamipennis (L.-A.)	10	..	..	10
*Aedes albifasciatus (Macq.)	132	..	..	132
n Aedes condolescens D. and K.	1	..	..	1
Aedes dorsalis (Meig.)	..	6	..	6
n*Aedes euiris Dyar	18	..	..	18
n*Aedes euplocamus D. and K.	2	..	..	2
*Aedes fulvithorax (Lutz)	2	..	..	2
*Aedes lineatopennis (Lud.)	..	7	..	7
n*Aedes mediovittatus (Coq.)	2	..	1	3
n Aedes obturbator D. and K.	1	..	..	1
n*Aedes pampangensis (Lud.)	..	1	..	1
n*Aedes polynesiensis Marks	..	3	..	3
n Aedes serratus (Theob.)	1	..	..	1
n Aedes sticticus (Meig.)	..	1	..	1
Aedes taeniorhynchus (Weid.)	..	27	..	27
Aedes vexans (Meg.)	..	13	..	13
n*Aedes vexans nipponii (Theob.)	..	2	..	2
n*Aedes vexans nocturnus (Theob.)	..	16	..	16
*Aedes vigilax (Skuse)	..	3	..	3
*Anopheles albitarsis L.-A.	23	..	..	23
n*Anopheles annularis V.d.W.	..	3	..	3
n*Anopheles annulipes Walk.	..	1	..	1
n*Anopheles barbirostris V.d.W.	..	2	..	2
Anopheles grabhamii Theob.	28	..	..	28
*Anopheles litoralis King	..	4	..	4
*Anopheles neomaculipalpus Curry	6	..	..	6
*Anopheles nigerrimus Giles	..	4	..	4
n*Anopheles punctimacula D. and K.	3	..	..	3
n*Anopheles sinensis Wied.	..	3	..	3
n*Anopheles subpictus Grassi	..	2	..	2
*An. subpictus indefinitus (Lud.)	..	40	..	40
Anopheles vestitipennis D. and K.	7	..	..	7
n*Culex americanus (N.-L.)	..	..	3	3
*Culex annulirostris Skuse	..	22	..	22
n*Culex fuscocephalus Theob.	..	4	..	4
n Culex peus Speiser	..	3	..	3
Culex pipiens L.	..	4	..	4
*Culex sitiens Wied.	..	8	..	8
Culex tarsalis Coq.	..	3	..	3
n*Culex tritaeniorhynchus Giles	..	6	..	6
n*Culex univittatus Theob.	1	..	..	1
n*Culex whitmorei (Giles)	..	65	..	65
n*Culiseta annulata (Schrank)	1	..	..	1
Culiseta inornata (Will.)	..	1	..	1
n*Mansonia crassipes (V.d.W.)	..	1	..	1
n*Mansonia dives (Schiner)	1	1	..	2
n Mansonia flaveola (Coq.)	9	..	..	9
*Mansonia humeralis D. and K.	9	..	..	9
*Mansonia pseudotitillans (Theob.)	1	..	..	1
n*Mansonia uniformis Theob.	..	10	..	10
Number of specimens	258	267	4	529
Number of species	20	31	2	51

* Asterisk indicates species not known to occur in any of three areas considered.
n—Species new to our aircraft inspection records.

transmitters, for instance, conceivably could have serious consequences.

Summary. Problems and practices involved in preventing escape of live mosquitoes and other insects of public health importance which are accidentally transported to the United States on aircraft are mentioned. Entomological findings, with particular reference to mosquitoes are discussed.

During the 13-year period ending June 30, 1960, more than 20,000 mosquitoes were found on arriving aircraft, in addition to a large number of other insects. Fifty-one of 92 mosquito species found are not known to occur in one or more of the three general areas (Continental United States, Hawaii, and Puerto Rico) where the aircraft disinfestation program is conducted. Four of the non-indigenous species, *Anopheles grabhamii, Anopheles neomaculipalpus, Anopheles vestitipennis,* and *Culex tarsalis* were alive when found.

Results point up the need for continuation of this preventive program to meet the threat of entry and establishment of exotic medically important insects in this country.

Acknowledgments

Grateful acknowledgment is made of the work of entomologists at the quarantine stations who conducted the program upon which this paper is based and to entomologists at the U. S. National Museum who made many of the taxonomic determinations.

References

1. World Health Organization. 1960. Sixth summary of cases of insecticide resistance in anopheline mosquitoes. WHO/Mal/266 Rev. 1; WHO/Insecticides/117 (Nov. 4), map + 12 pp.

2. Hughes, J. H., and Porter, J. E. 1958. Measures against yellow fever entry into the United States. Pub. Health Rep. 73(12):1101–1106.

3. U. S. Public Health Service. Regulations. Disinsectization requirements. 42 CFR 71.102–71.103.

4. World Health Organization. 1957. International Sanitary Regulations, Geneva, 120 pp.

5. Dunnahoo, C. L. 1943. Insect control on aircraft. Soap and Sanit. Chem. 19:111–113.

6. Hughes, J. H. 1949. Aircraft and Public Health Service foreign quarantine entomology. Pub. Health Rep. Suppl. No. 210. Washington, D. C., U. S. Government Printing Office, 38 pp.

7. Stone, Alan, Knight, K. L., and Starcke, H. 1959. A synoptic catalog of the mosquitoes of the world (Diptera, Culicidae). Pub. by The Entom. Soc. America, Washington, D. C., 358 pp.

BULLETIN NUMBER 4

One of the public services which members of AMCA should always be ready and willing to perform is to give authoritative information to public officials on how to organize for mosquito control. AMCA Bulletin Number 4, entitled "Organization for Mosquito Control" is designed to assist in performing this service. It is now available at $2.00 a copy from the office of the Executive Secretary, Mr. T. G. Raley, P. O. Box 278, Selma, California.

Edited by Harold F. Gray, assisted by many other AMCA members, and with a foreword by Dr. Fred L. Soper, this Bulletin conveys up-to-date, specific answers to the many questions that confront persons and groups who are interested in or charged with organizing for mosquito control. Chapter headings include "Why Organize," "How To Organize," "Financing," "State-wide Legislation" and other topics, and there are appendices of helpful references and sources of information.