

RAT CONTROL IN A PLAGUE OUTBREAK IN MALTA

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(With Plates 1 and 2 and 2 Figures and 1 Map in the Text)

1. INTRODUCTION

Bubonic plague broke out in Malta in June 1945. At the request of the Colonial Office the present writer spent 8 weeks in Malta during the months August to September advising the Government on methods for the destruction of rats. The present paper describes the rodent population of Malta; the recent distribution of plague and murine typhus; the control methods applied in Malta; and the results of control.

The sources of information have necessarily been numerous. Much of the data has been supplied by officers of the Medical and Health Department of the Government of Malta. In particular should be mentioned Dr A. C. Briffa, Acting Chief Government Medical Officer at the time of the plague outbreak; Prof. V. J. Mifsud, Analyst and Bacteriologist to the Government of Malta; Doctors J. Galea, J. Morana and E. Stilon, Medical Officers of Health; and Mr P. Cauchi, Rodent Control Officer. Valuable information has also been provided by the Naval, Army and R.A.F. establishments in Malta.

The plan for the systematic destruction of rats in Malta was carried out by these authorities with exceptional thoroughness and vigour, and it is thought that the experience of this campaign will be of interest to other health authorities faced with similar problems.

2. ECOLOGY

(a) General

The geology and climate of Malta are described by Harrison & Hubbard (1945). The Maltese Islands, of which Malta itself and Gozo are the only important ones, are entirely of sedimentary rock, with two layers of hard coralline limestone and one of soft Globigerina limestone. Almost all buildings are of soft limestone (Pl. 1, figs. 1 and 2). External walls typically have outer and inner skins of stone, with a filling of rubble and mortar. They are generally at least 2 ft. 6 in. thick. This type of structure provides rats with excellent nesting sites in the walls. The climate is that of the north sub-tropical zone, with a mean annual rainfall of 21.5 in. Most of this rain falls during the winter.

The population of Malta itself is 243,500, of whom 179,400 live in the cities, their suburbs or outskirts. The density is approximately four persons per acre, or 2526 per square mile; this is three times that of England.

The rat problem in Malta was thus primarily that of a densely populated sub-tropical area. But there is also a rural problem, since the dry, shallow soil of Malta is intensively cultivated, with potatoes and wheat as important crops. Citrus trees, olives, carobs and prickly pear are generally distributed where the ground is fertile. Fields are small and bordered by rubble walls (Pl. 1, figs. 1 and 2; Pl. 2, fig. 3). There is thus plenty of cover for rats even in the dry season.

Gozo is a smaller island than Malta, generally similar, but less densely populated and more agricultural.

(b) Wild mammals

Wild mammals include *Rattus norvegicus* Berkenhout, *R. rattus* L., *Mus musculus* L. (the house mouse), and *Oryctolagus cuniculus* L. (the rabbit); Miller (1912) also mentions two species of weasel, but these were not observed. Weasels are mouse eaters and, even if present, are not of significance for rat control.

Table 1 gives the figures for rats trapped in the year beginning 1 October 1944. The dominant rat is *Rattus norvegicus*, the common brown rat of Western Europe. In Malta it infests food stores, private dwellings, shops and sewers in the towns; tips and farms in the countryside. The piles of rubble in Valletta and the Three Cities, due to bombing, were believed to harbour rats, but it is doubtful if they were important: the important question was not whether shelter was available, but whether there was food. For the reasons already given there is shelter for *R. norvegicus* everywhere in Malta and Gozo. In the agricultural areas the only sites of infestations which were clearly of hundreds of rats were refuse tips. Farm buildings and their surroundings were usually infested but not very heavily as a rule, at least during the dry season, when these observations were made. The impression gained was that rats were often in twos or threes, sometimes in tens or twenties, but rarely more. The heaviest infestations of farm buildings seen were in

* Infestation Control has now been transferred to Ministry of Agriculture and Fisheries.

Gozo. The main sites of burrows, apart from buildings and yards, were the bottoms of the rubble walls and the bases of prickly pear trees (Pl. 2, figs. 3 and 4).

The other species of rat, *R. rattus*, the so-called black or ship rat, is also found throughout Malta. Unlike *R. norvegicus* it nests above ground, and in buildings in Malta it behaved in the manner familiar in Britain, often infesting roofs and upper floors and nesting in walls and other suitable cover. It was reported to nest in trees in the countryside, but this was not seen. The three main colour varieties are all present in Malta, namely, *R. rattus rattus* L., which is black (at least on the back); *R. r. alexandrinus* Geoffroy, grey-brown; and *R. r. frugivorus* Rafinesque (also called *tectorum* Savi), which has a tawny brown back and pale belly. Inland, nearly all *R. rattus* are of the last type.

3 were refuse collectors, and a fourth was a son of one of the 3; 5 others were associated in work, or topographically, with refuse collection.*

By the end of 23 December 1945 there had been 75 cases with 20 deaths. (Systematic rat destruction as described below began in August.) Since then, only 5 cases have been diagnosed; on 2 February, 2 March and 3 at Zebbug in the 2nd week of June. The last 3 occurred during the week before Zebbug was due to be systematically disinfested. There had been no previous cases of plague there.

The final figures were 80 cases, with 22 deaths, giving a case mortality of 27.5% (see Text-fig. 1).

The map shows the distribution of plague cases. Where an individual lived and worked in different places he is recorded on the map at the place where other cases were identified. Thus, if a man worked

Table 1. *Rats examined in bacteriology laboratory, October 1944–September 1945*

	Total <i>a</i>	<i>R. norvegicus</i>		<i>R. rattus</i> all varieties		<i>R. rattus</i> var. <i>frugivorus</i>	
		Total <i>b</i>	% (<i>b</i> × 100)/ <i>a</i>	Total <i>c</i>	% (<i>c</i> × 100)/ <i>a</i>	Total <i>d</i>	% of <i>R. rattus</i> (<i>d</i> × 100)/ <i>c</i>
From naval dockyard	9,884	8,865	89.7	1019	10.3	234	23.0
From all other sources	29,395	27,511	93.6	1884	6.4	1449	77.0
Total	39,279	36,376	92.6	2903	7.4	1683	57.9

The above figures were kindly supplied by Prof. V. J. Mifsud, Government Analyst and Bacteriologist. Nearly all the rats were obtained by trapping: Since the two species may react differently to trapping, and since the trapping was not done at random, the figures cannot be taken to show the relative numbers of the two rat species, except very approximately.

3. PLAGUE IN MALTA

Plague has been recorded in Malta in 1813, 1917, 1936–7 (see Bernard, 1937), and 1945. Of the outbreaks in the present century that in 1917 was of only 8 cases. In 1936–7, in a period of 13 months, there were 33 confirmed cases with 12 deaths. It was observed in this outbreak that a significant proportion of cases was among persons associated with refuse disposal. In 1945 the first definite case was diagnosed on 17 June, and was from Hamrun. It soon became evident that there were two main areas involved: a large one including Marsa (the commercial port area), Msida, and part of Birkirkara; and a small one centred at Bubaqra. As is usual in such outbreaks (see e.g. Wu Lien-Teh, Chun, Pollitzer & Wu 1936), the majority of infected persons were accustomed to walking about in bare feet in filthy surroundings which provided harbourage for fleas. In Tower Road, Bubaqra, in which most of the Bubaqra cases lived, there were three privately owned refuse heaps. At one of these three *R. norvegicus* infested with bacteria indistinguishable from *P. pestis* were taken. Of 13 cases in Bubaqra,

in the dockyard (which was certainly a plague area) and lived in an inland village where there was no plague, his case would be recorded on the map as belonging to the dockyard.

There were no cases of plague in Gozo.

During the period under review the examination of rats brought in dead (from whatever cause) was continued.† From June 1945 to June 1946 inclusive, out of 22,902 examined, 659 were *R. rattus*. Of this total, 20 rats were diagnosed as infected (see Table 2) and of these 15 were *R. norvegicus*. It will be noticed that this species is clearly implicated as an important vector of plague in this outbreak (see Barnett, 1946). Although there was evidence of a widespread epizootic there was evidently a low incidence of infection; there were no reports of heavy mortality among rats which could be attributed to plague.

* This information was kindly supplied by Dr J. Morana, Medical Officer of Health.

† Spleen smears were made from every rat brought in. When bacilli suggestive of plague were seen, cavies or white rats were inoculated and later examined post-mortem. Further cultures were also made from them.

Plague was also identified in one family of pet cavies and suspected in another. Both of the households concerned had human cases of plague as well.*

Table 2. *Rats infected with plague*

	Date	Species	Sex	Place caught
1	28. vi. 45	<i>Rn</i>	♀	Bubaqra
2	3. vii. 45	<i>Rn</i>	♂	Bubaqra
3	3. vii. 45	<i>Rn</i>	♂	Bubaqra
4	5. vii. 45	<i>Rn</i>	♂	Bubaqra
5	2. ix. 45	<i>Rf</i>	♀	Victualling yard
6	9. ix. 45	<i>R₂</i>	♀	Victualling yard
7	28. ix. 45	<i>Rn</i>	♂	Dockyard
8	7. x. 45	<i>R₂</i>	♂	Dockyard
9	11. x. 45	<i>Rn</i>	♂	Zabbar
10	15. x. 45	<i>Rf</i>	♂	Zurrieq
11	18. x. 45	<i>Rn</i>	♀	Zabbar
12	30. x. 45	<i>Rn</i>	♀	Cospicua
13	18. xi. 45	<i>R₂</i>	♂	Dockyard
14	19. xi. 45	<i>Rn</i>	♂	Dockyard
15	19. xi. 45	<i>Rn</i>	♂	Dockyard
16	1. xii. 45	<i>Rn</i>	♀	Qormi
17	1. xii. 45	<i>Rn</i>	♀	Valletta
18	22. i. 46	<i>Rn</i>	♀	Dockyard
19	22. i. 46	<i>Rn</i>	♀	Dockyard
20	29. i. 46	<i>Rn</i>	♀	Corradino Road

Total rats 20 (out of 22,243 *Rn* and 659 *R₂* examined June 1945–June 1946 inclusive).

<i>R. norvegicus</i> (<i>Rn</i>)	15
<i>R. rattus rattus</i> and <i>alexandrinus</i> (<i>R₂</i>)	3
<i>R. rattus frugivorus</i> (<i>Rf</i>)	2

4. TYPHUS

Flea-borne typhus is endemic in Malta and Gozo. Its incidence for the period October 1944 (when it was first recorded) to February 1947, is shown in Text-fig. 2.

The map shows the distribution of human cases of flea-borne typhus over a shorter period, and illustrates that the infection must have been generally present in the rat population of Malta.

5. MEN, METHODS AND MATERIALS

(a) Men

One of the early tasks of the present writer was to attempt the training in modern control methods of men from the Health Department and the three services. During August 1945, 146 persons attended introductory courses of lectures and demonstrations. They included civilian medical officers, sanitary inspectors, and rat catchers, and equivalent grades in the Navy, Army and R.A.F. Practical instruction

* The Government of Malta has now made a Regulation that guinea-pigs may not be kept without a licence. It is understood that the effect of this Regulation will be to prevent the keeping of guinea-pigs anywhere in the Maltese Islands except in experimental establishments such as the bacteriological laboratory.

was given during visits to sites where control was in progress.

At the beginning of October 1945, the numbers of men working directly on rat destruction were as follows:

Health department	69 including 11 in Gozo.
Naval dockyard	66 (under a Commander).
Other naval establishments	3 (under a Sub-Lieut.).
Army	35 (under a Lieut., R.A.M.C.).
R.A.F.	9 (under a Warrant Officer).

The Civil Department also provided a Rodent Control Officer who was responsible, under the Chief Government Medical Officer, for co-ordinating the whole campaign and for arranging the supply of materials from a central pool.

(b) Methods

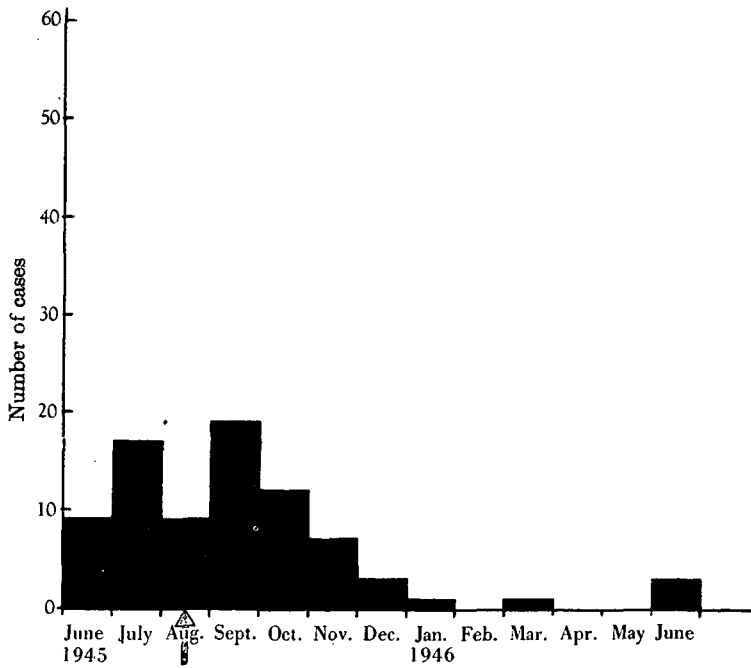
As soon as plague broke out the Medical and Health Department undertook large-scale trapping and poisoning. Red squill and barium carbonate were used in the main, together with some zinc phosphide and arsenious oxide. In some areas infestation had, by the beginning of August, been treated with all four poisons. The method of baiting was direct poisoning; that is, the poison baits (which were mostly small biscuits) were laid without previous prebaiting with plain bait. Large-scale trapping was carried out continuously in the naval dockyard and in a number of military and other establishments. However, both the civil authority and the army had already begun to use prebaiting in some places.

A description of new methods devised during the war has now been published, and those recommended for the U.K. will be found in the handbook of the Ministry of Food (1946). For the scientific basis of the methods the Reports of the Bureau of Animal Population should be consulted. (See also the important paper by Chitty & Shorten, 1946.)

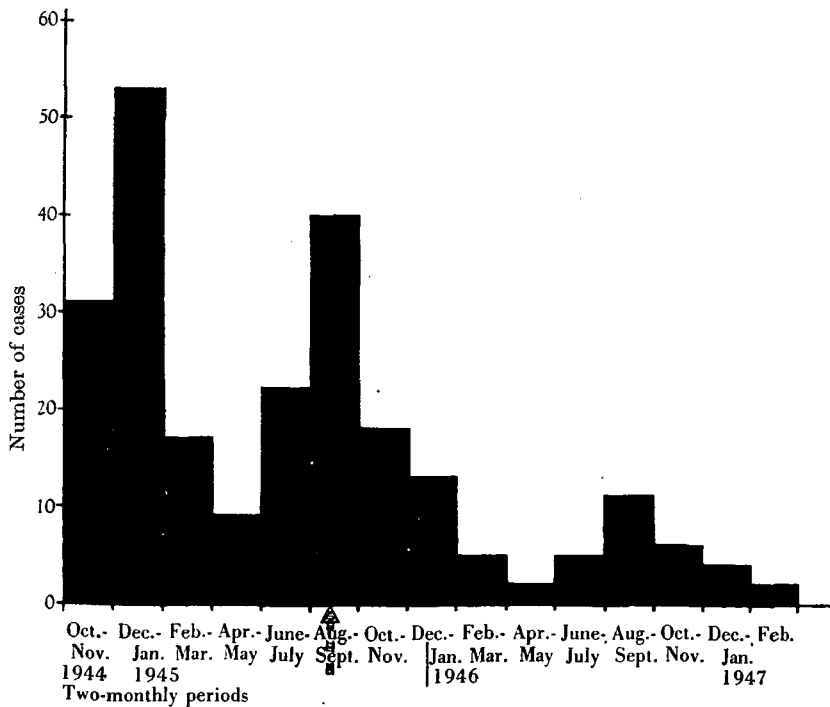
There was no possibility of doing research to test whether the methods used in the U.K. were applicable in Malta. They were therefore used without major modification. Perry & Watson (unpublished) had recently shown that they could be used in Palestine. The main features of the methods were as follows:

(1) Prebaiting followed by poison baiting was used throughout. Plain bait was laid for 4 or 5 nights, and the same bait mixed with a poison of known efficacy on the 5th or 6th night.

(2) A fortnight after a poison baiting a different plain bait was laid at the points previously baited, to test for residual infestation. Where takes of this post bait were observed, baiting was continued again for 4 or 5 nights, after which a new poison was added.



Text-fig. 1. Malta. Cases of bubonic plague, June 1945 to June 1946.



Text-fig. 2. Malta. Cases of murine typhus, Two-monthly periods.

(3) Treatments were carried out over the whole area of an infestation irrespective of the ownership or tenancies of land or buildings ('block control').

This method can be effectively applied only after an exceedingly detailed and careful survey has been made for traces of rats. This makes it possible to distribute the baits to intercept the rats in their movements between nests and feeding sites.

Baits were laid in holes where possible; or in the open, on rat runs; or, where there was danger from poison to domestic animals or children, in bait containers. Where there were sewers, baits were laid at the bottom of each manhole, if necessary on a tray. (See Ministry of Food, 1946, for description of bait containers and sewer trays.)

Trapping was not recommended as a control measure except for very small residual populations. Intensive trapping with large numbers of traps may bring about a reduction in a rat population, but after a time no further reduction is achieved, since the effects of trapping are balanced by breeding (Morgan, Fisher & Watson, 1942, 1943). In the Malta dockyard over 10,000 rats were trapped and paid for during the year ending August 1945. Yet the baiting campaigns afterwards undertaken showed that there was still a heavy rat population. Trapping of this kind is known to set up a condition known as 'trap-shyness'. What trap-shyness implies can be illustrated by the fact that when it was believed that plague had appeared in the naval victualling yard, 136 traps were set for 3 successive nights to get bodies for bacteriological examination. Only 3 rats were caught.

Poisoning was carried out before any attempt was made to improve cleanliness or to proof buildings, since disturbance of food and cover might lead to a dispersal of rats and to an alteration in their regular diurnal movements. The more regular these movements the easier it is to distribute baits so that they intercept the rats. This is common sense, and it is supported by direct observation: Doty (1945) has, for example, observed how disturbance of cover in sugar-cane fields in Hawaii has caused widespread dispersal of the rat population.

Cleaning and proofing were, however, regarded as essential parts of a treatment. Conditions in civilian food stores were found to be unsatisfactory in these respects. This state of affairs has, since 1945, been drastically altered, and the change is considered by those on the spot to have been an important factor in bringing about a reduction of infestation.

(c) *Materials*

The following were used as bait bases:

(1) Wheat, soaked for 12–24 hr. in water, excess water poured off.

(2) Sausage rusk (a biscuit meal) mixed with an equal weight of water.

(3) Barley treated in the same way as wheat.

The bases were to be used in that order, but from 29 April 1946, owing to shortage of wheat, barley was used as the first choice of bait base. In general, only two bait bases were required, owing to the low takes recorded after second treatments. Some third baiting treatments were begun in July 1946, but it was found that takes were so low as to make them not worth while. Small residues after second treatments were therefore, as a rule, disposed of by trapping with breakback traps.

The poisons used were:

(1) Zinc phosphide (5 % or, later, 2.5 %).

(2) Arsenious oxide, of fine particle size and refined (10 %).

(3) Red squill powder (10 %) or extract, both of a quality vouched for by H.M. Government. Where there was considered to be special danger from the use of poisons red squill was used as a first choice, since it is much less toxic to man and domestic animals than the other two.* It should be made clear that it was only possible to recommend the use of red squill preparations because H.M. Government was able to arrange a supply of materials which had been properly bio-assayed and were known to be of high toxicity to *R. norvegicus*.

(4) At a relatively late stage alphanaphthylthiourea was used, at 2 %, in cases of special difficulty.

The quantities used during the 12 months from the beginning of systematic poison treatments in August 1945 were approximately as follows:

	lb.
Wheat	32,000
Sausage rusk	14,000
Barley	4,000
Zinc phosphide	720
Arsenious oxide	360
Red squill powder	220

1261 P3 (box) bait containers were used, and 6319 drainpipe containers.

The above methods were recommended for both rat species, except that red squill was not recommended for use against *R. rattus* since there is some evidence (not yet published) that it is not satisfactory. Doty (1945) and Johnson (1945) have also reported failure of red squill against *R. rattus*.

* From August 1945 to November 1946 compensation was paid for the accidental poisoning of 28 fowls, 3 goats and 1 sheep, at a cost of £47. None of these deaths was due to red squill. There were no instances of poisoning of human beings.

6. TREATMENTS AND RESULTS

The campaign by the civil authority fell into two main parts: first, the areas in which plague was occurring were given special attention; second, all built-up areas and farms were systematically treated for rats. During the first phase sewers were treated in conjunction with surface premises; that is, only neighbouring manholes were baited ('vertical block control'). In the second phase sewer systems were treated as a whole, independently of surface treatments. Meanwhile, establishments belonging to the Navy, Army and R.A.F. were also systematically treated. Where infestations overlapped areas belonging to different services, either the departments concerned carried out simultaneous treatments, or one department made itself responsible for the whole treatment.

The first areas to be given large-scale, systematic block treatments were (a) one involving part of Birkirkara, part of Hamrun and the whole of Msida; (b) the port areas of Marsa; and (c) the naval dockyard. In addition, smaller treatments were undertaken in various scattered areas; of these, the most important was at the large refuse tip at Luqa and neighbouring R.A.S.C. horse transport lines.

Bubaqra, which early appeared as a plague centre, had been dealt with very drastically in July 1945, before the new methods were put in force. Direct poisoning with various baits had been done; infested refuse dumps had been burnt; and a general clean-up of houses, yards and roads had been carried out. By August there was little evidence of rats and no further treatment was attempted at that time. Three treatments proved to be necessary later in 1945 in different parts of the area.

The early treatments by the new methods were of special importance, since their results gave evidence on the efficiency of the recommended methods in the conditions prevailing in Malta. Some of the treatments at this early stage were in part directly observed by the present writer; and it was possible to draw some provisional conclusions from them.

One example was provided by the naval victualing yard, where both species of rat were present. The main food was sacked cereals, split peas and lentils. Owing to the occurrence of plague cases three treatments were given in successive weeks, respectively with soaked wheat and arsenious oxide, damp sausage rusk and zinc phosphide, and soaked barley and zinc phosphide. (This involved a departure from the recommended baiting sequence, but the reasons for it had only a local application. The use of zinc phosphide in two successive treatments is, in particular, not desirable.) In the north section of the yard 5 days' prebaiting gave an average of 42 baiting points showing take. In the second treatment the corresponding figure

was 5. In the third treatment, on 4 successive days, the recorded numbers of points showing take were 4, 1, 0, 2. It is likely that in this small section, after the last treatment with poison bait, complete clearance had been achieved. In the middle section, in the first treatment, the average number of points showing prebait take was 56; in the second it was 7.

Another early operation was carried out by the Army at the refuse tip at Luqa and the neighbouring R.A.S.C. horse transport lines. Some ploughed fields with stone walls were included. The rats here were *R. norvegicus*, and were feeding partly off fodder and partly off the refuse tip, and living in burrows in the earth or in rubble. Soaked wheat and zinc phosphide were used. There were 127 baiting points, and at 107 poison take was recorded. Damp sausage rusk was laid at all these points a fortnight after the poisoning. No take of this post bait was recorded at any point. There is thus evidence that, in this instance, there was complete clearance with one treatment.

These early successes were not followed by a completely uniform series of further successes. Table 3 gives summary figures of the results of baiting for the period of 6 months beginning February 1946. Figures for the earlier period are not given because less information is available. The naval dockyard figures are shown separately, and cover the 10 months beginning August 1945.

Treatments outside the dockyard gave, on the whole, fairly consistent results. The reduction in the number of points showing poison take in second treatments is typically in the neighbourhood of 88%. It should be made clear here that this reduction is not a direct measure of the reduction in the number of rats. This point is discussed in the next section. For the dockyard, the figures are less satisfactory. These results too, are discussed in the next section.

Sewers were in some places given special treatment independent of surface infestation. In Valletta a first treatment was given in December 1945 with damp sausage rusk and zinc phosphide. It was estimated that of 546 oz. poison bait laid, 436 oz. was taken. In August 1946 a further treatment with wet bread and zinc phosphide was given: 704 oz. was laid and 129 oz. was estimated to have been taken.

Apart from comparisons of the records for successive treatments there are two ways in which the effects of control on a rat population can be assessed. In the first place, if (as was the case in Malta), the general population is highly conscious of the rat menace, reports by the public are of value. Such reports have throughout the campaign given a favourable impression of its effects. In March 1947, for example, complaints from Valletta were described as 'negligible'. In October 1946 inquiries

Rat control in a plague outbreak in Malta

were made in 367 premises in Valletta, including shops, stores, offices and bakehouses. Of these premises, eleven were found to show signs of minor rat infestation and twenty-three to have mice. Similar reactions from the inhabitants of Marsa and the Manderaggio slum of Valletta have been reported. In general, when the presence of rats has been reported in the areas treated in the first months of the campaign, it has not proved necessary to

7. DISCUSSION

Some conclusions can be drawn on (a) the degree of clearance achieved; (b) the extent to which clearance is maintained over a relatively long period, such as a year; (c) the level of organization and technique required to get the results described.

Assessment of the degree of clearance has to be made from baiting results recorded by semi-trained

Table 3. Summary of treatments

	No. of baiting points			Points where poison take observed			
	Treatment 1 <i>a</i>	Treatment 2 <i>b</i>	(<i>b</i> × 100)/ <i>a</i> <i>c</i>	Treatment 1 <i>d</i>	(<i>d</i> × 100)/ <i>a</i> <i>e</i>	Treatment 2 <i>f</i>	(<i>f</i> × 100)/ <i>d</i> <i>g</i>
February 1946 to August 1946							
Civil establishments	33,596	4301	12.8	25,824	76.9	3017	11.7
Army	538	77	14.6	268	50.7	38	14.2
R.A.F.	469	256	54.6	304	64.8	165	54.3
Naval (not dockyard)	935	146	15.6	554	59.2	120	21.7
August 1945 to April 1946							
Naval dockyard	16,646	5411	32.5	7,154	42.9	2320	32.4

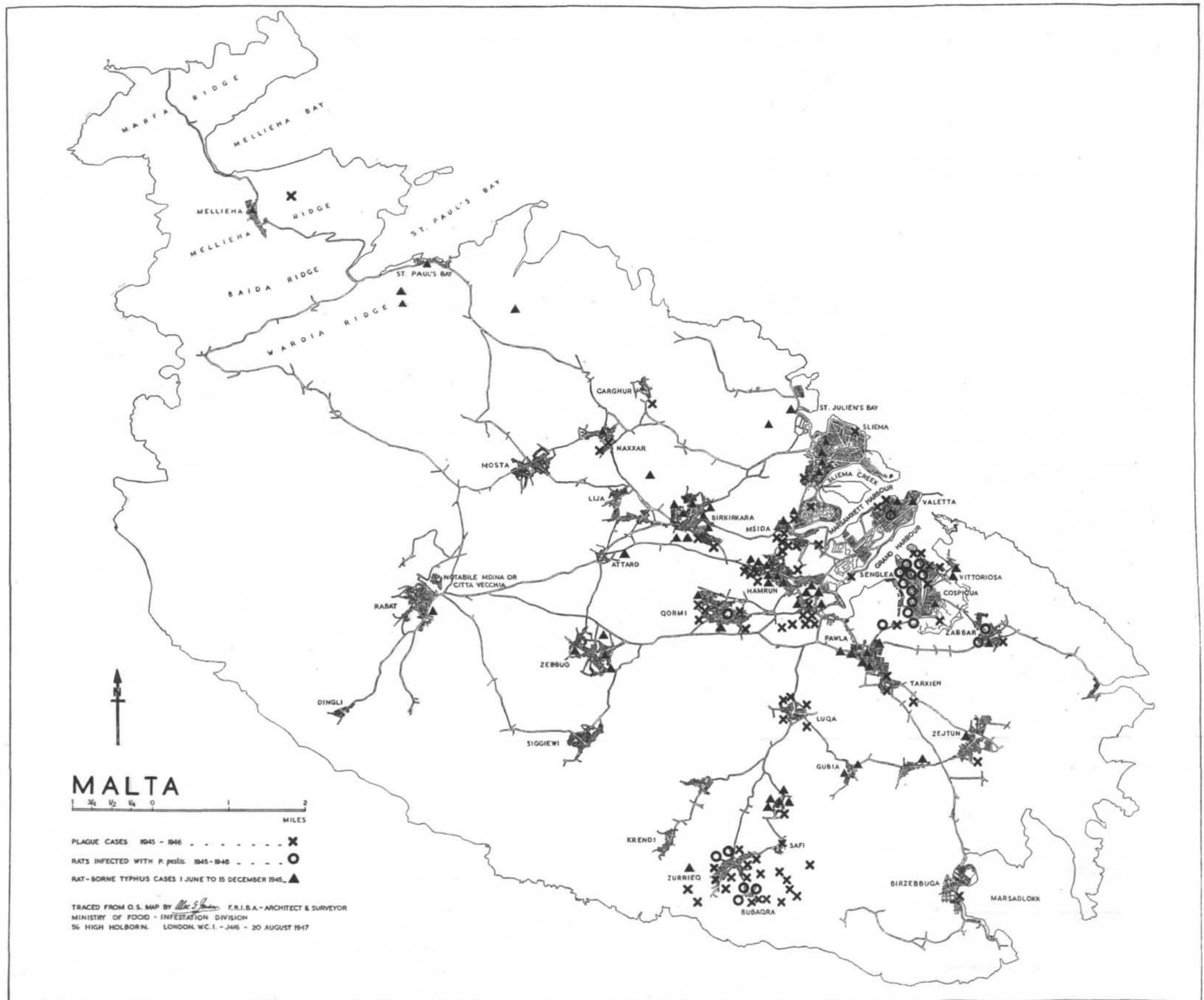
Table 4. Tests of reinfestation

Place	Date of original baiting	Original treatment No. of points showing		Reinfestation test Jan. 1947. No. of points	
		Prebait take	Poison take	Laid	Showing take
1 Qormi: dwellings	Aug. 1945	22	20	12	1
2 Valletta: slum	Sept. 1945	80	47	40	8
3 Birkirkara: dwellings, farms	Sept. 1945	49	47	25	4
4 Marsa: waterfront warehouses	Oct. 1945	196	58	100	17
5 Qormi: dwellings, shops	Dec. 1945	55	45	30	5
6 Floriana: dwellings, stores	Jan. 1946	39	39	20	0
7 Paula: dwellings, farms	Apr. 1946	104	40	60	0
8 Vittoriosa: dwellings	Apr. 1946	70	62	35	5
9 Paula: dwellings	July 1946	80	62	40	2
Totals		695	420	362	42

treat a whole block again. The complaints, in the words of the Rodent Control Officer, 'originated from the presence of odd rats'.

Despite these reports, a more objective test was needed. Tests for reinfestation were therefore carried out in nine selected areas. The results are shown in Table 4. The period between the original treatment and the test varied from 17 to 6 months. Each test consisted of laying 2 oz. soaked wheat at about half as many points as were baited in the original treatments. The wheat was left for 3 days and then examined. Of the total of 362 test baits, 42 (11.6 %) showed take; 15 (4.1 %) showed a complete take.

workers. There may consequently be a good deal of error, and there is no means of estimating how large the error is. Figures have, therefore, been given only for the numbers of points at which take was recorded, since it is fairly easy to observe whether bait has been taken or not. The estimated amounts have been ignored. The figures derived in this way are likely to suggest a lower degree of clearance than has, in fact, been achieved. In general, where there is a dense rat population treatment is likely to bring about a reduction in the rat population higher than the reduction in baiting points visited. (See Barnett, 1947, with reference to this effect in sewers.)



The figures given in Table 3 suggest that treatments outside the naval dockyard gave a satisfactory clearance. This is confirmed by the fact that when third treatments were undertaken they were found to be unnecessary. In addition, in 1946 only 5 cases of plague occurred, and of these 3 occurred together in Zebbug, in June. The obvious inference is that 4 months' intensive rat destruction had checked the plague outbreak. Unfortunately, it must be admitted that this inference is not a safe one, since plague outbreaks always come to an end even if nothing is done to kill the rats or their fleas. It cannot be proved that in this instance it was rat destruction that was responsible. However, the fact that the only cases of plague in the summer of 1946 were in an untreated village is suggestive.

The figures for flea-borne typhus, which is an endemic disease, reflect more certainly a reduction in the rat population.

On the whole, lack of success, where it occurred, seems to have been generally due to one of two things: (a) the area treated was too small, and re-invasion took place comparatively rapidly from neighbouring properties; or (b) too few baiting points were used. The first reason, though an obvious one, cannot be too often emphasized, especially where, as in Malta, rats are widely and diffusely distributed. The danger of re-invasion is particularly acute where sewers are infested. The experience in Valletta and other built-up areas was that 'vertical block control', involving the treatment of sewers as well as of surface premises, was very important.

As for the second reason for comparative failure, the outstanding example is the naval dockyard. The work there was of a high standard, but the difficulties were quite exceptional. Rats were distributed throughout the dockyard; there was a great deal of cover, from large masses of equipment and materials to piles of rubble due to bombing; food was provided not only in the various stores, but also by the leaving of food scraps by the dockyard labourers. It seems likely that the only way of achieving satisfactory clearance in these conditions is to combine an improvement in hygiene with exceptionally extensive and 'wasteful' baiting. In some areas it might be necessary to lay baits at regular intervals, of, say, 12 ft. round the edges of obstacles. To do this requires a big force of men, as well as much material.

At one stage the dockyard authorities believed that rats were entering the dockyard from Senglea. Treatments were carried out on the civilian side of the dockyard boundary but, of 115 baiting points, only eight were visited. It was concluded that invasion from neighbouring territory was probably negligible.

It has been argued to the present writer that the

destruction of rats in the sort of conditions prevailing in Malta is largely wasted effort, owing to the rapid restoration of the rat population by breeding. Certainly, with the old methods, which rarely gave anything like complete clearance, return to the *status quo* as a result of breeding must have been very rapid. For example, if a rat population were reduced by 50 %, and the sources of food not removed, the infestation would probably be restored in a few months. This, however, would not apply if there were no rats left, or even if there were a residual population of about 5 %. The gestation period of a rat is about 3 weeks and maturity is not reached for 3 or 4 months (Donaldson, 1924; Asdell, 1946). Litters may number 8 or more, but a high infantile mortality must often occur in the wild. It can, therefore, be seen, without elaborate calculation, that 5 rats are not going to become a 100 in a matter of a few weeks. This purely inferential statement is supported by the results of the tests summarized in Table 4. It seems likely that these very satisfactory results were due (a) to the systematic treatment of large areas (which prevented re-invasion); (b) to the consistent application of two poison treatments with different baits (which ensured very high percentage kills); (c) to the extensive cleaning up and proofing of buildings such as food stores which were particularly likely to support large rat populations. (For comparison with work on a larger scale in England and Wales, see a preliminary report by Barnett, 1947.)

None of this would have been possible without a rigorous technique and an organization employing large numbers of men; nor would it have been possible if the civil authority and the service establishments had failed to carry out a combined campaign. Macdonald (1945) has emphasized the general importance of large-scale organization and planning for public health in backward areas. The rat campaign in Malta had the dual function of preventing disease and of preserving food stocks. From whichever aspect it is regarded, it provides an example of effective control due to the combination of well-tested techniques with adequate organization.

SUMMARY

1. Methods of rat destruction devised in the United Kingdom during the war were applied to combat plague in Malta.

2. The species were *Rattus norvegicus* Berkenhout, and *R. rattus* L. The first is the more common and played an important part in carrying plague.

3. In the last 7 months of 1945, 75 cases of plague were diagnosed. In 1946, 5 cases occurred. A marked fall in the incidence of flea-borne (murine) typhus occurred in 1946.

4. Systematic rat destruction began at the end of

August 1945. The method was prebaiting, followed by poisoning with baits and poisons of known efficacy and change of both bait and poison for follow-up treatments. For this purpose a large organization in which the Navy, Army and R.A.F. took part, as well as the Medical and Health Department, was set up under unified control. This made it possible for large blocks and areas to be treated as a whole and within a short space of time.

5. Evidence is given that the degree of clearance achieved by these methods was satisfactory. Comparison of the figures of baiting points visited in first and second baiting treatments suggests, in most instances, a satisfactory kill; this is confirmed by the fact that third treatments, when they were carried out, were found to be unnecessary. Reports from the public and house-to-house inquiry also suggest a very great reduction in rat population.

6. In January 1947, 9 tests for reinfestation were carried out in areas which had been treated between 6 and 17 months before. These tests indicated that few or no rats were present. It is therefore suggested that not only had a good initial clearance been achieved but that the effect was a lasting one.

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EXPLANATION OF PLATES 1 AND 2

PLATE 1

Fig. 1. Typical agricultural land in Malta, with rubble walls and some trees.

Fig. 2. Site of a refuse tip at the back of a house in Bubaqra. (This was a plague centre, and was one of the places at which plague-infested rats were found. The tip had been burnt when this photograph was taken.)

PLATE 2

Fig. 3. Rubble wall, with traces of rats at the base (runs and scraps of paper and other material dragged up by the rats).

Fig. 4. Rat hole at the base of a prickly pear tree.

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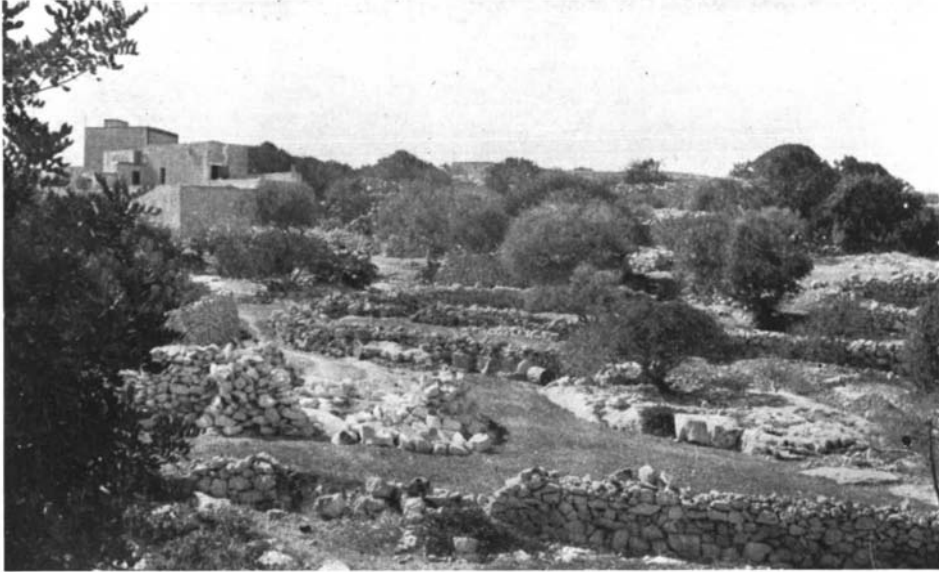


Fig. 1



Fig. 2



Fig. 3



Fig. 4