OBSERVATIONS ON THE ECOLOGY OF *ORYCTES* (COLEOPTERA: SCARABAEIDAE: DYNASTINAE) IN MADAGASCAR

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Plates IV–VII

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In May, 1966, the author was sent under the auspices of the United Nations/South Pacific Commission Rhinoceros Beetle Project * to Madagascar and the Comores Archipelago to conduct an investigation of the natural enemies of the species of *Oryctes* occurring there. The object of this study was to search for parasites, predators and diseases of these beetles, which might be introduced to the islands of the South Pacific to control the introduced *Oryctes rhinoceros* (L.) which has become a serious pest of coconut palms in the area.

Eleven species of *Oryctes* occur in Madagascar, and five species in the islands of the Comores Archipelago (Paulian, 1959).

In Madagascar the major plantations of coconut palms occur on the north and central west coast; in other coastal areas the coconut palms are scattered in gardens, around villages, or in avenues along streets, and are not in general planted in large regular plantations. Most localities mentioned in the text are shown on Fig. 1.

On the west coast of Madagascar there is a marked seasonal difference in rainfall, the climate being very dry, almost rainless, from May to November, while the season of rains usually occurs from December to April. On the east coast there is no marked seasonal difference in rainfall, the climate being humid throughout the year.

Throughout this paper the abbreviations L1, L2 and L3 are used to denote first-, second- and third-instar larvae of *Oryctes*, respectively.

Damage by *Oryctes* to coconut palms in Madagascar

Details of damage by *Oryctes* to large coconut plantations, and smaller plantings, in the various coastal areas of Madagascar visited, are presented in Table I.

It appeared, in the main, that on the large coconut plantations, *e.g.*, Ankivanja, Andilana, where plantation sanitation involving the destruction of breeding sites (dead standing coconut palms, decaying coconut trunks and stumps) is carried out regularly, damage to the crowns of the palms is kept at a very low level. On the other hand, a coconut plantation at Mahilaka which had been destroyed by *Oryctes* (Plate IV, fig. 1), contained many dead standing palms that provided abundant breeding sites.

In large plantations such as Madiromiarina, Ampanitoina, Mahilaka and Vohemar, where there are sections containing a smaller number of very tall old

* Joint United Nations Special Fund and South Pacific Commission Research Project on the control of the coconut palm rhinoceros beetle in the South Pacific Region. Project Headquarters at Apia, Western Samoa.

TABLE I. *Occurrence of damage by* Oryctes *to coconut palms in areas of Madagascar visited*

Name of plantation	Size of plantation: no. of palms or area of planting (hectares)	Palms		*Oryctes*		Notes
		Planted in regular rows	Age (years)	Breeding sites	Damage caused	
Ankivanja	22,000	Yes	35 to 40	Very little dead coconut wood. Dead standing palms rare	*Oryctes* damage to crowns negligible	Many pigs roam through plantation and may destroy larvae. Plantation surrounded by dry scrub containing satra palms in which *Oryctes* larvae breed
Madiromiarina	14–15,000	Yes	Average 10; a few 20 to 30	Any breeding sites destroyed or inspected periodically	Short palms little attacked. Most attacks concentrated on the few much taller older palms	
Ampanitoina	47 ha.	Yes	20 to 40	Most breeding sites destroyed or inspected	A few fronds of tall palms attacked; short palms not attacked at all	Plantation situated in region of mangrove swamp
Mahilaka	About 10,000	Yes	30 to 50	Many dead standing palms, decaying trunks and stumps. Plantation abandoned	Crowns of tall palms heavily attacked while shorter palms less attacked	Plantation surrounded by forest, in which *Oryctes* larvae breed in rotting logs to a small extent
Andilana (on Isle Nossi-Be)	7,500	Yes	Oldest 50. New ones added each year	None	Very little	
Dzamandzar (on Isle Nossi-Be)	Several thousand	No	40 to 50	Wind-felled coconut trunks common but not sufficiently decayed for *Oryctes* breeding	Rather few *Oryctes* attacks	
Antetikireja	10,000	Yes	20 to 30. Also younger palms and seedlings	None	Almost none	Traps for larvae, consisting of piles of *Raphia* fronds, set up in plantation. Larvae removed regularly from soil beneath traps in rainy season
Ivovona	About 250	Growing in irregular formation throughout village	15 to 30	Very little rotting wood	Most palms have 1 to 2 fronds attacked, but are not seriously damaged. Coconut seedlings often attacked	
Bobasakoa	50 ha.	Yes	1 to 2	Few	About 10% of seedlings lost due to *Oryctes* attacks to base of stem	Plantation surrounded by dry scrub with little rotting wood

TABLE I—(*continued*)

Name of plantation	Size of plantation: no. of palms or area of planting (hectares)	Palms		*Oryctes*		Notes
		Planted in regular rows	Age (years)	Breeding sites	Damage caused	
Andramasay	20 ha.	Yes	15 to 30	A few dead standing palms	No heavy *Oryctes* damage	
Bethell (near Morondava)	260	Yes	20 to 25	Some dead standing palms and rotting logs	Moderate to fair amount of *Oryctes* damage	
Betanimena (near Tulear)	200	Yes	About 30	None	Very little	Group of 500 date palms aged 40 years also present, not attacked by *Oryctes*
Anjiabe (near Tulear)	200	Yes	7 to 8	Very little	Light to moderate attacks to fronds. One coconut palm, much taller than the others, had 8 fronds attacked by *Oryctes*	Crop of cotton planted between rows
Vohemar	Extensive	Yes	Some sections with tall palms aged about 40. Other sections with palms 10 to 15	Many tall dead standing palms. Also numerous decaying coconut logs and stumps	The few tall palms still living showed fairly heavy *Oryctes* damage. The sections of shorter palms showed surprisingly little damage	
Antsiraikiraiky (on Isle Sainte Marie)	45 ha.	Some in rows, some in clumps as coconut palm jungle	Some 60. Many 8 to 10	Many dead standing palms, also decaying coconut trunks	Only moderate damage to fronds	Moderate number of palms knocked down by wind and continuing to grow. Also palms leaning at various angles
Mananjary	285	In 2 rows along road facing beach	Tall, about 30	Very few	Very occasional and slight	
Lokaro	About 10 ha.	Mostly scattered or in clumps	About 50	Moderate number of dead standing palms, decaying trunks and stumps present	Fair amount	Plantation abandoned 30 to 40 years ago, now much overgrown with scrub
Ambinanikely	About 200	Yes	Very tall old palms	Very small number of dead standing palms, trunks and stumps	Palms at northern end of plantation with much wind show little *Oryctes* damage, while on interior, towards southern end where there is less wind, palms have moderate to heavy damage to fronds	

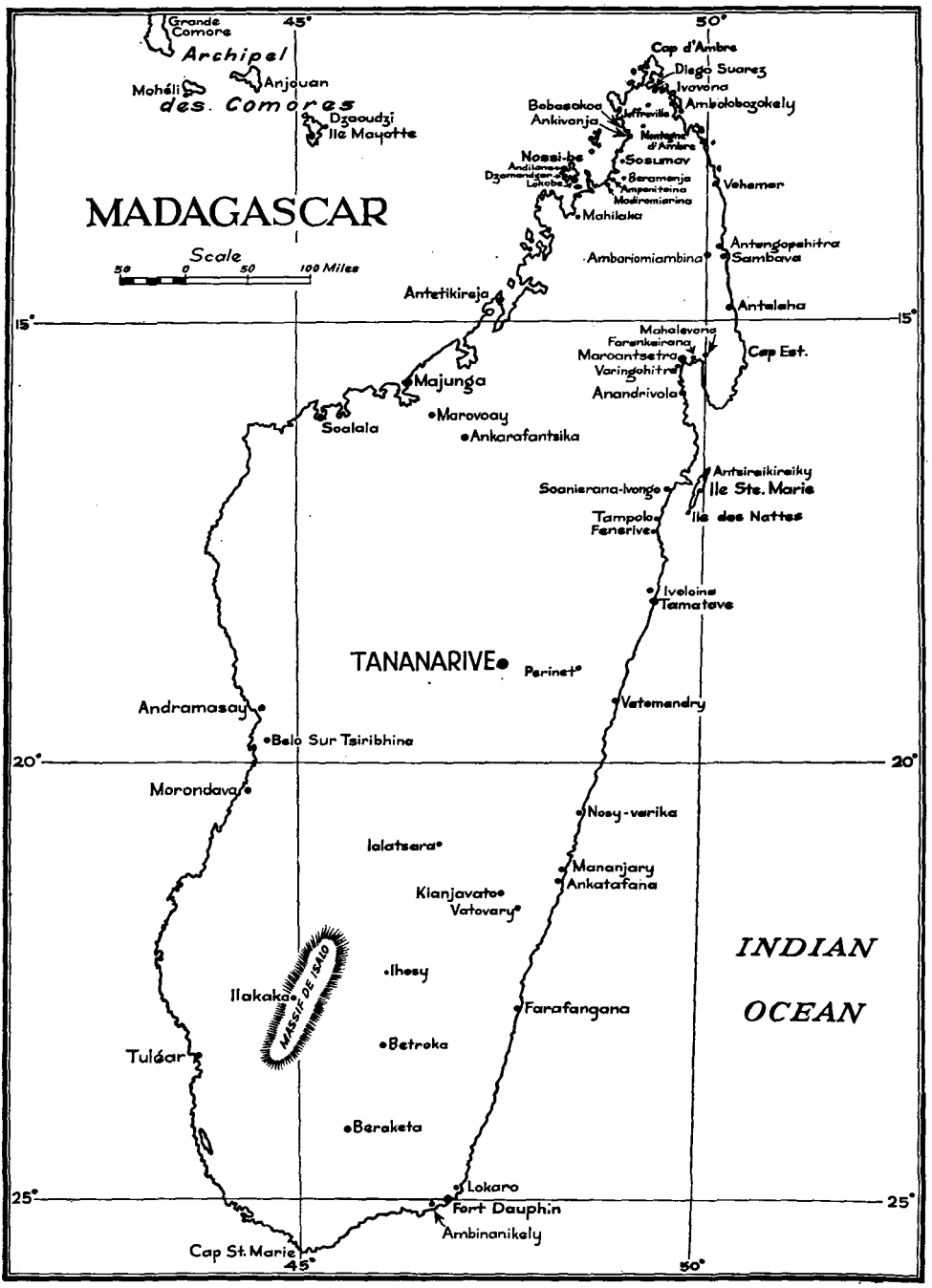

Fig. 1.—Map of Madagascar, showing localities mentioned in text.

palms among many younger shorter palms, the attacks of *Oryctes* seemed to be particularly concentrated on the crowns of the tall palms while the shorter palms were slightly attacked or had escaped attack completely. Perhaps this is because the crowns of tall coconut palms towering over lower palms are relatively more conspicuous and so more readily found by the beetles when in flight.

Breeding sites

Coconut wood

Dead standing palms and stumps.—Examples of *Oryctes* breeding in the tops of dead standing coconut palms in various coastal locations in Madagascar are presented in Table II.

Larvae of *Oryctes*, and a smaller number of adults, often occur in a large central hole up to 4 m. long in the top of the dead coconut palm (Plate IV, fig. 2). The hole is filled with moist chewed rotten wood, dark brown or black in colour, and moist faecal pellets (frass). Considerable numbers of large larvae (on the north west coast often third instars of *O. gigas* Lap.) can occur together in these holes, and each larva does not occupy a separate gallery (Plate V, fig. 1). Though *Oryctes* larvae will bite readily when disturbed, they can apparently live together in large holes filled with a soft medium of chewed wood and frass without injuring one another.

When tall dead standing palms were felled, the tops often smashed open on hitting the ground, and the larvae were ejected. Some larvae rapidly turned blue, with symptoms of the so-called " blue disease ", and died. Dissection showed the foregut to be ruptured. This confirms the finding of Marschall (1963), that in consequence of an external trauma, for instance, by the shock of a falling palm tree, one or more of the delicate diverticles of the gut may rupture, oozing liquid poisons into the haemolymph, thus causing the blue colour, which within minutes spreads from the wound throughout the body.

An adult of *O. gigas* was found in the top of a dead standing palm at Bethell near Morondava. It is interesting to note that this is the first report of this species occurring so far south along the west coast.

Decaying coconut logs.—Examples of *Oryctes* breeding in decaying coconut logs are presented in Table III.

Sometimes considerable numbers of large larvae occur together in the hollowed out interior of a rotting log filled with moist chewed wood and frass. Elsewhere the larvae occupy individual galleries separate from one another.

Larvae move to firm intact parts of the wood for pupation. For instance, in the plantation at Mahilaka in October a small coconut stump was found to have the upper part filled with moist chewed wood and frass, while the basal part consisted of moist, but still intact wood in which 15 pupae of *O. gigas* were embedded head uppermost, each in its separate cell.

Satra trunks

Larvae of *Oryctes* (probably *gigas*) breed in quite high numbers in decaying logs and trunks of " satra " (*Medemia* sp., Borasseae) in the dry scrub surrounding the coconut plantation at Ankivanja. One piece of rotten dry satra trunk, 3·6 m. long, contained 40 L3 in a central tunnel filled with wood powder and frass. Another similar piece, 1·9 m. long, contained 32 L3 and another, 2·4 m. in length, contained 15 L3 in a central tunnel filled with moderately moist chewed wood and frass. Though decaying satra trunks are quite dry externally, a moderate amount of moisture is retained in the parts inhabited by larvae of *Oryctes*.

In a very dry sandy plain with numerous scattered clumps of satra palms near Ambolobozokely in the north-east of Madagascar, one piece of decaying satra trunk, 4 m. long, was found to contain two *Oryctes* L3 with much dry wood

TABLE II. *Occurrence of stages of* Oryctes *in tops of dead standing coconut palms in parts of Madagascar visited*

Place	Date	Height of tree (metres)	Larval stages (no.) Eggs (no.)	L1	L2	L3	Pupae (no.)	Adults (no.) *O. gigas*	*O. blucheaui*	*O. simiar*	*Oryctes* sp. ? indet.	Notes
Ankivanja	August	9·5	4	6	—	—	—	2	—	—	—	
		8·5	—	5	2	4	—	3	—	—	—	
		11·3	—	5	2	8	—	1	—	—	—	
	September	9·0	—	—	—	13	—	1	1	—	—	
		10·5	—	1	2	—	—	1	1	—	—	
		14·0	3	—	—	3	—	2	—	—	—	
		12·75	6	—	—	6	—	2	—	—	—	
Madiromiarina	August	8·4	—	—	2	—	1	1	—	—	—	
		14·0	2	4	—	7	—	1	—	—	—	
		12·3	—	—	—	8*	—	—	—	1	—	* 1 dead
		14·6	—	23	1	—	—	1*	—	—	—	* dead
		13·4	—	—	—	21	—	—	—	—	—	
		12·5	—	3	3	2	1	1	—	—	—	
		19·1	—	5	2	12	—	—	—	—	—	
Ampanitoina	September–October	10·5	—	—	—	—	4	—	—	—	—	
		18·0	—	—	—	18	—	—	—	—	—	
		15·6	—	—	—	20	—	—	—	—	1	
		11·3	2	12	10	1	—	1	—	—	—	
		10·9	—	—	3	1	—	2	—	—	—	
		14·8	—	—	10	30	—	—	—	—	—	
		16·3	—	—	10	—	—	—	—	—	—	
		13·0	—	—	—	—	—	1	—	—	—	
Mahilaka	August	8·0	—	—	—	31	—	—	—	—	—	
Marovoay	March	8·4	—	3	1	29	—	—	—	—	—	also *O. gigas* elytron, 8 Cetoniid larvae and 2 small bats
		4·0	—	—	—	16	—	—	—	—	—	
		3·6 stump	—	—	—	34	1	—	—	—	—	131 Cetoniid larvae

TABLE II—(*continued*)

Place	Date	Height of tree (metres)	Larval stages (no.) Eggs (no.)	L1	L2	L3	Pupae (no.)	Adults (no.) *O. gigas*	*O. blucheaui*	*O. simiar*	*Oryctes* sp. ? indet.	Notes
Andramasay	February	7·0	—	—	—	39	—	—	—	—	—	also 1 brown Elaterid larva present
Bethell	February	9·2	—	—	—	—	—	1	—	—	—	
Vohemar	October	2·5 stump	—	—	1	11*	3	—	—	6	—	* includes 1 prepupa
		4·2 stump	—	—	—	16*	1	—	—	—	—	* includes 3 prepupae
Fenerive	December	tall	—	—	—	5	—	—	—	—	—	
		tall	—	—	7	6	—	—	—	—	—	
		3·0	—	—	10	10	1	—	—	—	2*	* probably *O. pyrrhus*, of which 1 emerging from pupal case, also 2 adult ♂ prothorax remains
Vatomandry	January	2·9	6	7	—	—	—	—	—	—	—	6 brown Elaterid larvae
		12·6	—	1	—	—	—	—	—	—	—	2 large Elaterid larvae
		10·2	—	—	—	—	—	—	—	—	—	top had 1 *Oryctes* L3 head capsule, 1 large Elaterid larva and 1 Elaterid adult
		18·0	—	—	3	—	—	—	—	—	—	1 Elaterid larva and 1 Elaterid adult at top
Mananjary	March	15·5	—	1	2	—	—	—	—	—	—	
		8·7	12	5	13	6	—	—	—	—	—	1 large and 1 small Elaterid larvae
Farafangana	January	11·6	—	—	—	—	—	—	—	2*	—	* both females
Lokaro	April	fairly tall not noted	—	1	4	4	—	—	—	—	—	
		not noted	—	—	1	17	—	—	—	—	—	
Ambinanikely	April	4·6	—	—	—	10	—	—	—	—	—	

TABLE III. *Examples of* Oryctes *breeding in decaying coconut logs*

Locality	Date	Length of trunk (metres)	Eggs (no.)	Larval stages (no.) L1	L2	L3	Pupae (no.)	Adults (no.) and species	Notes on stages and other arthropods present
Mahilaka	August	1·5	—	—	3	2	1	1 (*simiar*)	1 centipede
		2·1	—	—	6	17	—	—	1 centipede
		0·9	—	—	6	15	—	—	1 centipede
		3·8	—	—	4	12	—	1 (*simiar*)	plus 1 L3 dead in ants nest. Also 1 L3 dead with *Metarrhizium*
		6·8	—	—	1	3	6*	1 (*simiar*)	* 1 dead
		0·4	—	—	—	2	1	—	Also 1 pupa attacked by *Metarrhizium*
		2·8	—	—	17	16	—	—	
		2·1	—	2	2	11	—	—	2 centipedes, 8 millipedes
Bethel (near Morondava)	February	small	—	14	2	3	2*	1** (*gigas*)	* Small perhaps *O. boas*. ** elytra soft, light brown, freshly metamorphosed. Also 1 old *O. gigas* dead in gallery
Vohemar	October	2·5	—	—	11	21*	1 (probably *O. pyrrhus*)		* includes 1 prepupa
		1·0	—	—	—	8	—	2 (*simiar*)	
Mahalevona	December	0·7	—	—	—	6*	4	3	* includes 2 prepupae
Ambinanikely	April	1·0	—	—	—	5	—	—	

powder. However, though there is much decaying satra wood in this region, larvae of *Oryctes* were rarely found.

Other decaying wood

In forests.—Larvae of *Oryctes* were not commonly found in the forests of Madagascar. This may be due to a limitation in food supply for the adults, as the indigenous palms are scattered among many other different types of plants and may be difficult for the adults to locate. Also adults may experience difficulty in finding suitable breeding sites in the forest, whereas coconut logs and stumps in plantations and villages provide them in abundance.

Details of *Oryctes* breeding sites found in forests are presented in Table IV.

TABLE IV. *Examples of* Oryctes *breeding in forests in Madagascar*

Forest locality	Date	Details of breeding sites and material collected
Joffreville	July	1 piece rotting wood with 2 L3 *Oryctes* & 2 Scoliid cocoons (1 empty, 1 with pupa)
		1 piece rotting wood, 70 cm. long with 1 *Oryctes* larva dead with *Metarrhizium*
		1 piece rotting wood, 30 cm. long with 1 *Oryctes* larva and 1 large centipede
		1 piece rotting wood, 60 cm. long with *Oryctes* galleries containing 2 cast pupal skins and L3 head capsules
Mahilaka (in forest surrounding abandoned coconut plantation)	August	1 dry trunk, 10–15 m. long with 1 L3 and 1 adult *O. simiar* in galleries filled with frass
		1 rotting log, 3 m. long with 2 L2, 1 L3 living, and 1 dead blackened and chewed L3.
		1 rotting log, 2 m. long with 6 L1, 8 L2, 4 L3, 1 pupa *Oryctes*
6 km. south of Beramanja	August	1 stump, 1·5 m. high with top riddled with an abandoned *termites nest; in rotten but intact wood below this were* 3 L3 in galleries, and 1 black centipede; at base of stump a nest of black ants.
Lokobe (on Isle Nossi-Be)	August	1 rotten mango log with 9 L2, 1 L3 and 1 *Oryctes* adult. The adult and a dead L3 were together in same gallery. The dead L3 had head severed and blackened injuries on abdomen—perhaps had been killed and chewed by adult. Ants nest close by in same log, also galleries of Passalid larvae and adults
Antongopahitra	October	1 decaying log with 4 L3 in galleries
		1 decaying log with 2 L3 in galleries
Forest between Sambava and Antalaha	October	1 log with 1 L3 in tunnel in cocoon of chewed compressed wood, about to pupate
		1 moist rotting log with 1 *Oryctes* adult.
Antalaha	November	Many pieces of wood in small cleared area surrounded by forest
		1 rotting piece with 1 L3
		1 rotting piece with moist interior with 2 L3, also 7 Passalid larvae, 2 Passalid adults, 11 Lucanid larvae, 1 Cerambycid larva, ants nest, and 2 black millipedes in galleries
Varingohitra	December	1 large moist rotting log with 1 L3 and 1 Lucanid larva
		1 stump 0·6 m. high with 1 L3 in gallery
Farankairana	December	1 rotten moist stump with many galleries with 1 L3, also 4 Lucanid larvae, 1 Cerambycid larva, 11 Passalid adults
3 km. north of Anandrivolo	December	1 dead L3 lying on leaf litter near piece of decaying native palm
Tampolo	December	1 moist rotting log with 1 L2 and 3 L3 in galleries
		1 rotten piece wood with 1 L1
Perinet	December	1 log-wood hard but with galleries with 1 *O. ranavalo* pupa in cell, 4 Cetoniid larvae and 11 Cerambycid larvae
		1 small moist stump with 1 L3
Vatovary	February	1 partly decayed stump with 2 L3 in galleries

In open cleared areas.—Larvae were found in decaying logs and stumps in open cleared areas, away from both forests and coconut palms. Just north of Soanierana Ivongo on the central east coast, in an open area between the beach and a swamp, a pupa of *O. simiar* Coq. was found in hard wood in a partly decayed stump (not coconut). Another log on the ground was mostly hard, but contained two *Oryctes* L3 in a rotten layer just under the bark.

At Ivoloina near the Agricultural Station just north of Tamatave on the east coast, two pieces of moist decaying Niaoulis wood at the edge of a rice field each contained one *Oryctes* L3. Another piece of Niaoulis contained an *Oryctes* pupa. Small numbers of Cetoniid, Lucanid and Cerambycid larvae were also present. One moist, soft, but not very rotten piece of "Tulipier du Gabon" (*Spathodea campanulata*) trunk contained one L2 and one L3 *Oryctes*.

Oasis of Ilakaka.—At Ilakaka in the interior of Madagascar on the western edge of the very dry Massif d'Isalo, there is an oasis and stream dominated by many tall "Vakaka" palms (*Ravenala madagascariensis*), and by "Fandra" palms (*Pandanus humbertianus*). The Vakaka palms are nearly always in the centre of the oasis standing in the water, whereas the Fandra palms are mostly at the edge, though they can occur among the Vakaka palms. The oasis is surrounded by vast dry prairie grasslands with scattered *Medemia* palms.

Some 24 moist decaying palm trunks and stumps were examined in the oasis in March, but only six contained larvae of *Oryctes*. One old Vakaka stump filled with moist rotten wood and soil contained three L1, nine L2 and eight L3 *Oryctes*. Another old Vakaka stump filled with moist rotting wood contained one adult female of *O. ranavalo* Coq. There was no evidence of *Oryctes* damage to the crowns of the palms in the oasis.

Decaying wood of Albizia

In the coffee plantations along the south-east coast of Madagascar trees of *Albizia stipulata* have often been grown as high shade for coffee. There is often a considerable amount of decaying *Albizia* wood in the plantations, and this is used by *Oryctes* for breeding. About 10 km. west of Mananjary a decaying trunk of *Albizia* at the edge of a coffee plantation was found to contain galleries filled with frass and chewed wood which harboured eight *Oryctes* L3, also one Lucanid larva and one Lucanid adult. Some of the *Oryctes* L3 contained numerous white cysts in the abdomen symptomatic of a protozoan gregarine infection.

At Manakana, about 20 km. west of Mananjary, in a gallery in a moist decaying stump of *Albizia*, one *Oryctes* L3 was found which clearly showed many white gregarine cysts in the abdomen.

In the coffee plantation of the Société Nantaise along the banks of the Mananjary River about 20 km. west of Mananjary, one piece of decaying *Albizia*, 3 m. long, was found to contain five *Oryctes* L3 in separate galleries with frass and chewed wood, also one pupa of *Oryctes*. One of the larvae was in a cell 2 cm. from the surface of the log. One moist rotten trunk of *Albizia* 5·85 m. long contained seven L2 and nine L3 *Oryctes* also one *Oryctes* pupa dead and blackened. One piece of moist rotten *Albizia* 2 m. long contained one L3, also one adult female of *O. simiar* in an oval cell 5 cm. long and 3 cm. high, 5 cm. from the surface of the log.

Raphia

Larvae of *Oryctes* were occasionally found in decaying *Raphia* trunks. In December at Aniribe on the Isle Sainte Marie off the east coast of Madagascar three decaying *Raphia* trunks, moist and rotten inside, were found to contain one L1 and one L2 *Oryctes*, and one brown Elaterid larva. On Isle des Nattes

at the southern tip of Isle Sainte Marie, one *Raphia* trunk, moist, partly fibrous and partly rotten, contained two L2 and six L3 *Oryctes*. Another moist rotten *Raphia* trunk contained one adult female of *O. ranavalo*.

Near Nosy Varika on the central east coast in January one decaying Raphia trunk in a rice field contained one pupa of *Oryctes* covered with white *Metarrhizium*, another dead pupa, two living pupae, one dead L3 and two living adults of *O. simiar*. Another piece of *Raphia* contained one dead L3 and one dead adult of *O. simiar*.

In the forest of Anakarafantsika on the central west coast, one piece of moist *Raphia* trunk contained one pair of elytra of an *Oryctes* and larval faecal pellets, but no larvae.

Maize and rice husks

In February, in a heap of old well-decayed maize husks at Bethell near Morondava on the west coast, five dead adult specimens of *O. boas* were found, also eight L2 or L3, and in some heaps of rice husks an adult male of this species was found.

Manure

In February, at Antasakamirohaka near Morondava, some 179 healthy larvae of *Oryctes*, mainly L2 and L3, were found in approximately 6·3 square metres of dry manure at the edge of a cattle pen.

In April, in the village of Ambondrobe, on the plateau about 46 km. south of Betroka, 90 healthy larvae of *Oryctes*, mostly L3, and two Cetoniid larvae were found in about 0·8 square metres of dry manure at the edge of a cattle pen. The remains of a dead adult of *Oryctes* were also found. The occurrence of *Oryctes* larvae in this habitat is very interesting as there are no palms in the village, which is surrounded by savannah grassland with scattered trees, but with apparently no forest or jungle with native palms, or coconut palms.

Feeding sites

Coconut palms and coconut seedlings

Adults of *O. gigas* and *O. blucheaui* Fairm. were found with larvae in the tops of dead standing coconut palms on the north-west coast, and presumably these adults attack the crowns of living coconut palms.

At Marovoay near Morondava in February a male and a female of *O. simiar* were extracted from a vertical hole 66 cm. long which they had made in the heart of a coconut palm about six years old. The female had 23 large mature eggs in the ovaries. At Betanimena near Tulear in March an adult of *O. simiar* was found in a hole about 60 cm. long in the heart of a five-year-old coconut palm.

In December at Antetezambe near Maroantsetra on the east coast, one adult male of *O. simiar* was removed from a hole at the base of a frond on an eight-to-ten-year-old coconut palm. At Soanierana near Maroantsetra an adult of *O. simiar* was removed from a hole 9·5 cm. long in a frond base through which it was attacking the heart of a five-year-old coconut palm. Just north of Tamatave, in the village of Ambodivolo in January, two adult males of *O. simiar* were found together in a hole in the heart of a coconut palm aged about eight years.

In the plantation at Antetikireja on the north-west coast, adults of *O. pyrrhus* Burm. attack newly planted coconut seedlings, burrowing into the earth to make a hole at the junction of the stem and the nut. In a small clearing in the forest on the north-east coast near Cap Est seven adults of *O. pyrrhus* were collected by searching in the soil close around the bases of some coconut

seedlings that were being attacked. This was interesting, as the clearing was quite surrounded by forest; no adult coconut palms were present, and the coconut seedlings had been planted only recently, yet the adults of *O. pyrrhus* had succeeded in locating them.

At Salazamay, close to Tamatave, there is a small plantation of coconut seedlings and palms aged about three years. These plants had been protected by lightly mixing aldrin dust with the surface soil around the base of each plant. On January 1, 1967, four adult males and two adult females of *O. pyrrhus* were found dead on the soil around the base of one plant, having been killed by the insecticidal treatment when they had burrowed through the soil to attack the plant. Four dead adults of the same species were found around the bases of two other treated plants.

Oil palms

At Ambariomiambina, about 8 km. west of Sambava on the north east coast, there is a five-hectare stand of four-year-old oil palms planted in rows. These palms are often attacked by adults of *O. pyrrhus* burrowing through the soil to make holes in the base (Plate V, fig. 2).

Ravenala *and other forest palms*

Two *Ravenala* palms at Kianjavato had leaves attacked by *Oryctes*, and on one of them, growing in a clump of bamboo, the beetle had made extensive holes at the base of the midrib of four leaves (Plate VI, fig. 1). An indigenous "Lafaha" palm growing in the forest of Ambatovaka near Kiankavato had three leaves that bore large V-shaped incisions typical of attack by *Oryctes*. In the forest at Perinet an unhealthy "Avinona" palm had five leaves that had been holed at the base by *Oryctes*. A "Letikitiky" palm had the crown stunted and bore only two leaves, each of which had the ends chewed in a V-shape, probably as the result of attack by *Oryctes*.

Bamboo

On the I.F.C.C. Station at Kianjavato some 38 adults of *O. ranavalo* were found in holes in the moist lateritic soil at the bases of bamboo plants, attacking the roots (Plate VI, fig. 2). There is much bamboo in this area, and most of the plants were attacked in this way. One had a hole in the top of the shoot, apparently made by *Oryctes*. These adults of *O. ranavalo* were collected in January and February, *i.e.*, in the warm season when the rainfall is highest.

Banana plants

At Ambia, about 6 km. east of Maroantsetra, in December a male adult of *O. simiar* was found in the base of a leaf of a banana plant, having made a hole 85 cm. long in the midrib.

Parasites of larvae

Scoliid wasps

Small numbers of Scoliid cocoons were found in decaying logs in various parts of Madagascar but were not common in any locality investigated. Data on these findings are presented in Table V. The following cases are of interest. In coastal rainforest south of Antongopahitra, a very rotten, moist, moss-covered log was found to contain three Scoliid cocoons (one of which was empty), and galleries filled with chewed wood contained three Lucanid larvae. One of the living Scoliid cocoons occurred in a small oval gallery filled with moist chewed wood powder, apparently made by a Lucanid larva, situated well within the log away from the surface. This suggests that Scoliids may parasitise

TABLE V. *Occurrence of Scoliids in Madagascar*

Locality	Date	Habitat	Scoliid breeding site	No. of Scoliid cocoons	Coleopterous larvae present	Notes
Joffreville	July	In forest on side of valley	Decaying log 10m. long	2*	2 L3 *Oryctes*, also 3 other Coleopterous larvae	* 1 empty
Sosumav (near Ambilobe)	July	Scattered coconut palms in large area of sugar cane growing	Coconut log	1	*Oryctes* larvae	
Vohemar	October	Coconut plantation	Rotting coconut stump with dry wood	1*	— (*Oryctes* larvae abundant in plantation)	* empty
5 km. south of Antongopahitra	October	Rain-forest near coast	Decaying log	3*	Lucanid larvae	* 1 empty
Between Sambava and Antalaha	October	Forest near coast	2 pieces decaying wood	2*	1 small Elaterid larva 5 Passalid adults 1 large Lucanid larva	* 1 empty
Antsiraikiraiky	December	Coconut plantation	3 decaying coconut trunks	4*	*Oryctes* L2 and L3 attacked with *Cordyceps*	* 1 empty
Isles des Nattes	December	Area of rice fields with scattered coconut palms	Decaying coconut stump	1	1 L3 *Oryctes*	
Fenerive	December	A few scattered coconut palms near beach	Decaying coconut log 1·5 m.	5*	3 L2 *Oryctes* 1 Lucanid larva 2 Lucanid adult	* 3 empty, 1 shrivelled
Perinet	June	In dense tropical mountain rain forest	2 decaying logs	4	Cetoniid larvae	
Lokaro	April	Abandoned coconut plantation on coast	Dead standing coconut trunk	9	*Oryctes* larvae	

Lucanid larvae, in addition to larvae of *Oryctes* which also occur in this locality (see Table IV).

At Fenerive a decaying coconut log 1·5 m. long, hard externally, hollow and rotten inside and filled with moist dark brown wood powder, was found to contain five Scoliid cocoons, of which three were empty, one was shrivelled and one unopened. A small number of *Oryctes* L2, Lucanid adults and a Lucanid larva were present.

In the tropical rainforest near Perinet a moss-covered log, very moist and rotten, lying across a stream above the water, contained 15 Cetoniid larvae in a number of galleries, and two Scoliid cocoons. Another moist, moss-covered rotting log lying on other branches with one end in a stream, also contained 14 Cetoniid larvae and two Scoliid cocoons. Adults of a species of *Scolia* were later reared from these cocoons. The association of Cetoniid larvae and cocoons of *Scolia* in the same log suggests that *Scolia* can parasitise Cetoniid larvae.

Among 39 decaying coconut trunks, stumps, and five dead standing coconut palms examined in the abandoned coconut plantation at Lokaro, only one breeding site was found to contain Scoliid cocoons. This was a small dead standing coconut trunk 4·5 m. high, the top half of which was filled with moist black rotten powder and contained nine Scoliid cocoons, along with three L2, 24 L3 *Oryctes* and one pupa of *Oryctes*.

Gregarines

As mentioned earlier, some larvae of *Oryctes* collected from a decaying *Albizia* trunk near Mananjary in January 1967 had prominent white cysts in the abdomen, clearly visible through the integument. The gregarine responsible has been identified as *Stictospora kurdistana* Theod., Eugregarina, and its development in the coelom of these larvae has been described by Tuzet and others (1967). A larva of *Oryctes* collected in August 1966 at Dzamandzar on the Isle of Nossi-Be contained 14 white cysts of which 12 were in a cluster on the inner surface of the body wall near the foregut. When the cysts were punctured a thick white paste of protozoan gregarine spores flowed out. Some of the cysts were brown or blackened, and possibly were undergoing encapsulation as a result of host defence reactions.

Larvae infected with the white gregarine cysts were not commonly found. At Dzamandzar only one larva of *Oryctes* out of 20 examined showed cysts, and at Ambinanikely (south-east coast) only one larva out of 32 collected in decaying coconut trunks was infected. Two larvae collected near Antalaha (north-east coast) were infected with cysts.

Some 39 decaying coconut trunks and stumps, and five dead standing palms, were examined at Lokaro in April, 1967, but only one stump contained any larvae infected with gregarine cysts. This stump was 1·4 m. high, and of 0·4 m. average diameter, firm outside and filled with moist powder and frass. It contained three L2 and two L3 *Oryctes* with many white gregarine cysts, and one L3 without cysts.

At Ankatafana near Mananajary in March, 1967, in a " Dara " palm stump and rootstock, about 0·8 m. in circumference and about 0·5 high and containing moist rotten dark brown wood powder, some 34 *Oryctes* L3 were found among the fibres and in the roots. A total of 23 of these L3 had from two to hundreds of white gregarine cysts clearly visible through the integument. Often hundreds of cysts occurred in masses in the abdomen between the gut and the body wall. The cysts appeared to be quite free in the body, for if the skin of an infested larvae was depressed, the cysts could easily be pushed about.

Some 18 Cetoniid larvae containing white gregarine cysts were found in decaying logs in the Montagne d'Ambre in the north of Madagascar.

Nematodes

External nematodes.—Of 17 *Oryctes* larvae collected in coconut wood on the ground in the plantation at Madiromiarina on 10 July, 1966, seven had masses of small white nematodes in the intersegmental creases on the anterior ventral surface and around the insertions of the legs. The larvae themselves appeared to be healthy. These nematodes were not found on any of 64 larvae collected from decaying coconut wood and dead standing coconut palms at Madiromiarina on August 15th and 17th.

Four out of 29 *Oryctes* larvae collected from decaying coconut trunks at Sosumav near Ambilobe in July also had white masses of external nematodes embedded in black material in the creases around the leg bases and in the overlapping intersegmental creases on the ventral surface.

Whether these nematodes are parasitic on the larvae or normally free-living in the decaying wood is not known, but the latter possibility is more likely as the larvae with nematodes on them did not seem to be unhealthy.

Internal nematodes.—Adult and larval Oxyurid nematodes (possibly *Schwenkiella* sp.) were found in the fermentation chamber of the gut of larvae of *Oryctes*. Some 25 per cent. of the larvae at Ankivanja contained 10 to 20 nematodes in the fermentation chamber. Nematodes also occurred in larvae of *Oryctes* from Sosumav, Madiromiarina, Mahilaka plantation and forest, Bermanja, Dzamandzar, Lokobe, Marovoay, Andramasay, Antsakomirohaka and Nahampoana (just north of Fort Dauphin). Cetoniid larvae from decaying logs in Ialatsara forest, Montagne d'Ambre, Ambariomiambina, Marovoasy and a locality 32 km. south of Baraketa also contained many nematodes in the fermentation chamber. Similar nematodes have been found in 33 per cent. of a sample of 100 larvae of *O. rhinoceros* collected in Western Samoa. The gut of these nematodes contained a brownish material resembling digested wood so it is possible that they are not parasitic in the fermentation chamber of larval *Oryctes*, but merely commensal there.

Fungal disease

Cordyceps *sp.*—In the coconut plantation at Antsiraikiraiky on Isle Sainte Marie, of 34 *Oryctes* L3 found in December, 19 (about 56%) were infected with a species of *Cordyceps*. The larvae were dead in their galleries in the coconut logs and had large thick yellow cords of the fungus growing out from their bodies into the decaying coconut wood (Plate VII). For example, a rotting trunk on the ground, the wood being soft and moist with much chewed powder, contained four dead *Oryctes* L3 and two dead pupae with thick yellow fungal strands growing out from the bodies. Some of the dead larvae had both *Cordyceps* and white *Metarrhizium* fungi growing on them. Another moist coconut trunk with a powdery interior contained three L3 dead with yellow *Cordyceps* strands growing out, two L2 apparently still healthy and two Scoliid cocoons.

This was the only locality in Madagascar where larvae of *Oryctes* attacked by *Cordyceps* were found by the author. T. V. Venkatraman (A preliminary report of an investigation of the possibilities of biological control of the coconut rhinoceros beetle (*Oryctes rhinoceros* (Linnaeus)).—South Pacific Commission cyclostyled paper, 1958) found one such larva killed by *Cordyceps* at Fenerive on the central east coast of Madagascar to the south of Isle Sainte Marie. J. Lepointe (Report on the *Oryctes* problem in Madagascar.—South Pacific Commission cyclostyled report, 1960) found seven examples of larvae and pupae of *Oryctes* infested with fungus (possibly *Isaria*) on Isle Sainte Marie and on the mainland opposite.

Metarrhizium anisopliae.—Clear cases of larvae of *Oryctes* having died in

their galleries in decaying logs as a result of infections by the green muscardine fungus *M. anisopliae* were rarely encountered. Only the following cases of apparent death due to *Metarrhizium* were recorded during the investigation. In the Mahilaka coconut plantation, of 94 larvae of *Oryctes* examined, only three had *Metarrhizium* infections. In the forest near Joffreville a piece of rotting wood, 70 cm. long, contained one *Oryctes* L2 larva covered with *Metarrhizium*. In the coconut plantation at Antsiraikiraiky on Isle Sainte Marie, *Metarrhizium* was associated with *Cordyceps* infestations. In a sodden, marshy rice field near Nosy Varika a moist decaying piece of *Raphia* trunk 1·5 m. long, had galleries containing a pupa of *Oryctes* covered with *Metarrhizium*, another dead pupa without obvious *Metarrhizium*, two living pupae, a dead L3 and two living adults of *O. simiar*. In the forest in the Montagne d'Ambre, of 252 Cetoniid larvae collected in decaying logs, only two cases of *Metarrhizium* were found.

The low incidence of manifestation of *Metarrhizium* infections under natural conditions in Madagascar is in agreement with the findings of Surany (1960) who reported that in a survey conducted in five countries of Asia less than 15 per cent. of *O. rhinoceros* displayed visible signs of *Metarrhizium* infection, while in Africa less than 5 per cent. of the specimens of *O. monoceros* (Ol.) and *O. boas* (F.) were killed by *Metarrhizium*.

Parasites of the adults

Nematodes

Some 90 per cent. of the males of *O. gigas* examined had nematodes on and between the membranes sheathing the aedeagus or in the aedeagus between the

TABLE VI. *Percentage of* Oryctes *adults with nematodes and (in brackets) numbers of insects found infested and total number dissected*

Species of *Oryctes*	Location of Nematodes			
	in aedeagus of males	in bursa of females	in coll. glands of females	under elytra of both sexes
O. gigas	90 (26/29)	90 (18/20)	95 (19/20)	52 (26/50)
O. blucheaui	100 (1/1)	66 (2/3)	100 (3/3)	25 (1/4)
O. simiar	29 (5/17)	17 (2/12)	50 (6/12)	10 (3/30)
O. boas	25 (1/4)	0 (0/1)	0 (0/1)	20 (1/5)
O. pyrrhus	33 (4/12)	0 (0/9)	66 (6/9)	10 (2/21)
O. ranavalo	28 (5/18)	0 (0/8)	63 (5/8)	4 (1/26)

parameres and in the fleshy ejaculatory duct itself (Table VI). They were also found in the aedeagus of specimens of *O. blucheaui*, *O. simiar*, *O. boas*, *O. pyrrhus* and *O. ranavalo*, but were of less common occurrence in the last four species.

Some 90 per cent. of the females of *O. gigas* dissected had nematodes in the

bursa copulatrix (Table VI). These nematodes resembled those found in the aedeagus of males. It is possible that they are transmitted by the male to the females and that the nematodes may live at the expense of the spermatozoa. However, their presence in the bursa does not seem to affect the ripening of the eggs in the oviducts. For example, four females of *O. gigas* (collected at Ankivanja on September 2, 1966) had totals of 19, 21 (2 specimens) and 22 large mature eggs in the ovaries, respectively, while the bursa in each was filled with a mass of these nematodes. In another female of *O. gigas* the ovaries were not seen, being atrophied in this insect, which was perhaps very old, and in another specimen the ovaries were abnormal, being replaced by colourless or white spheres; in both these insects the proximal end of the bursa was filled with a mass of nematodes.

Nematodes also occurred in the bursae of females of *O. blucheaui*, and of a small number of *O. simiar*, but were not present in females of *O. boas*, *O. pyrrhus* or *O. ranavalo*.

Small nematodes were found in the pair of small brown " colleterial " glands in the wall of the vagina, in 95 per cent. of females of *O. gigas* examined (Table VI). They also occurred in all three specimens of *O. blucheaui* examined, and were fairly common in *O. simiar*, *O. pyrrhus* and *O. ranavalo*. Nematodes were also found in the colleterial glands of one specimen of *O. rhinoceros* collected in Mauritius.

About 50 per cent. of the *O. gigas* of both sexes examined had tufts of small nematodes under the elytra at the wing bases (Table VI). These nematodes were also occasionally found on specimens of *O. blucheaui*, *O. simiar*, *O. boas*, *O. pyrrhus* and *O. ranavalo*. They appeared merely to be using the insect as a means of transport.

C. P. Hoyt (Report on the investigations of predators and parasites of *Oryctes* in East Africa (1961–1962).—7 pp. South Pacific Commission) reported that 80 per cent. of the *O. monoceros* specimens occurring along the coast of Kenya and Zanzibar had juvenile Cephalobid nematodes under the elytra and in the colleterial glands of females, and 90 per cent. had a species of Rhabditid nematode in the bursa copulatrix of females or in the aedeagus of males. The same author also reported (Report on the investigations of the factors affecting the populations of some dynastid beetles in the Territory of Papua and New Guinea (August 1962 to November 1962).—South Pacific Commission cyclostyled report) that in New Guinea, specimens of *O. centaurus* Sternb. could have two species of Angiostomid nematodes in the preputial glands of the aedeagus of males, and in the bursa of females, and also another type of nematode, probably a Cephalobid, in the colleterial glands of females and in the sheath of the aedeagus of males.

Two cases of parasitism of adults by Mermithid nematodes were found. On November 29, 1966, dissection of an adult female, possibly of *O. ranavalo*, taken at Diego Suarez in November 1966 revealed no nematodes under the elytra or in the bursa or colleterial glands, but a large specimen of a species of *Mermis* (Mermithoidea, Mermithidae) in the body tissue. The ovaries of this beetle contained a total of five large mature eggs. In the village of Ambia near Maroantsetra in December 1966, an adult male of *O. simiar* was found with nine large Mermithid nematodes in the body tissue, and with some smaller nematodes in the aedeagus. The testes of this beetle were, nevertheless, quite well developed, one testis having six lobes, the other seven.

Mites

Mites were commonly found on larvae and adults of *Oryctes*. On specimens of *O. gigas*, hundreds of large red mites belonging to the Mesostigmata, also

many smaller white mites, possibly Trombidiformes, occurred on the body and under the elytra on the wings. Mites were also found on the ventral surface of the body at the junction between the prothorax and the mesothorax. Though these different types of mites were often extremely numerous on the adults, the beetles did not appear to be adversely affected by them.

Predators of larvae

Elaterid larvae

In some localities, Elaterid larvae were occasionally found associated with larvae of *Oryctes* in breeding sites, but were not common and did not appear to be of great importance as predators of such larvae.

On a dry plain near Ambolobozokely a piece of dry rotten satra palm trunk about 4 m. long was found to contain two *Oryctes* L3, and a large Elaterid larva with a black head. One of the *Oryctes* larvae had 11 black marks on the body, apparently healed wounds.

In the coconut plantation at Ampanitoina a dead standing coconut palm 17 m. high with the top burnt, apparently as the result of lightning strike, had no hole in the top, but a brown Elaterid larva was present. Another dead palm, 18·5 m. high, had a central hole in the top containing moderately moist chewed fibre, in which was found an adult of *O. gigas* and a brown Elaterid larva.

At Mangalimaso on Isle Sante Marie a rotten coconut stump full of old *Oryctes* galleries contained three L1, two L2 and eight L3 *Oryctes* and one small brown Elaterid larva.

A dead standing coconut palm at Fenerive had the top half rotten, with moist chewed fibre and tunnels, and contained seven L2 and six L3 *Oryctes* also one large brown Elaterid larva. At Vatomandry a dead standing coconut palm, 13 m. high, rotten at the top and with moist dark brown powder and old galleries contained one *Oryctes* L1 and two large cream Elaterid larvae with black heads. Another dead standing palm 10 m. high was found with one large cream Elaterid larva, one Elaterid adult, and an *Oryctes* L3 head capsule in moist material under the bark at the top. Another small dead coconut palm contained in the moist fibrous rotting top seven small L1 *Oryctes*, six white eggs, and six brown Elaterid larvae with dark brown heads.

Damage by *Oryctes* to coconut palms in the Comores

The Comores Archipelago comprises the four islands of Grande Comore, Moheli, Anjouan and Mayotte situated to the north-west of Madagascar in the Mozambique Channel.

Grande Comore

This is the largest of the four islands in the Archipelago, and is dominated by the large volcanic Massif du Kartala (2361 m.).

There are many coconut palms growing densely along the western coast of the island, and these are not seriously attacked by *Oryctes*. The author was informed that many coconut palms were thrown down by a cyclone in 1950 and there was subsequently an upsurge in the number of *Oryctes* breeding in the decaying trunks, but there has been little trouble with *Oryctes* since that time. Also the Comoriens burn much of the dead coconut wood to heat coral to make lime for building, thus keeping down the amount of breeding sites.

In the large plantation of very tall coconut palms at Salimani, the palms are moderately attacked by *Oryctes* and occasional dead standing palms are present. There is a fair amount of decaying wood present, and 40 dead coconut

palm trunks lying on the ground were examined in November. In one trunk there was a central tunnel 3 m. long filled with moist rotten powder, and containing one L1, 20 L2 and 55 L3 *Oryctes*. Some 92 *Oryctes* larvae (mostly L3) were examined in this plantation: 86 appeared healthy and six were found dead in their galleries and covered with *Metarrhizium*. Of 22 dissected, some 15 contained nematodes in the fermentation chamber.

Some 24 adults of *O. insularis* were collected in the decaying coconut trunks, and two males and two females were dissected. One of the males had nematodes within the aedeagus. One of the females had 19 large maturing eggs in the ovaries, also masses of large white active nematodes in the bursa, and nematodes in the colleterial glands. None had any nematodes at the bases of the elytra.

Moheli

There are many coconut palms in plantations on this island, but they do not seem to be heavily attacked by *Oryctes*.

Some 28 decaying coconut trunks were investigated in various parts of the island and 13 L1, 35 L2, 207 L3, 10 pupae and 30 adults of *O. insularis* Coq. were collected. Some 63 L3 and five L2 were examined and all were of healthy appearance, none showing any sign of infection by *Metarrhizium* or parasitism by *Scolia*. None had any nematodes in the fermentation chamber.

Some of the adults died before dissection could be carried out. However, three females and one male were freshly killed. The male had no nematodes in the aedeagus, and of the three females, one had no nematodes, while two had nematodes in the bursa, but none in the colleterial glands.

Anjouan

On this island there are many coconut palms. Some bore evidence of moderate damage by *Oryctes* and had a few fronds cut, but the majority appeared to be quite healthy and not seriously damaged. Most of them, which grow quite densely in places, belong to the Comoriens, and are not planted in orderly rows. Not much decaying wood was seen. Coconut trunks, and a small number of rotting mango trunks, were examined in various parts of the island, and two L1, 16 L2, 118 L3, three pupae and 16 *O. insularis* adults were collected. As on Grande Comore and Moheli, most of the larvae of *Oryctes* were in the L3 stage, probably soon to enter pupation. Some 110 *Oryctes* L3 were examined, and all were of healthy appearance; ten were dissected, but only one had nematodes in the fermentation chamber. About 16 adults of *O. insularis* were dissected, and the results are presented in Table VII. One female had a total of 18 large eggs in the ovaries, and masses of large nematodes in the bursa; another had ten large eggs in the ovaries, and nematodes in the bursa. Two other females had the ovaries small and immature, and no nematodes in the bursa.

Mayotte

On this island most of the tall coconut palms occur in regular rows. In the large plantation of about 57,000 coconut palms at Kahani, nearly all the trees have one to three fronds attacked by *Oryctes*, but despite this the trees seem healthy and are not seriously damaged. Almost no dead standing palms are present in this plantation, and there is not a great deal of rotting wood.

Some five L1, 31 L2, 48 L3, nine pupae and 25 adults of *O. insularis* were collected.

At Coconi one piece of decaying "jacquier" trunk (*Artocarpus integer*), 3·5 m. long, contained one L2 and seven L3 *Oryctes* in galleries, with frass

and chewed wood. A piece of decaying mango trunk contained two L3. A piece of decaying coconut trunk, 1 m. long, contained one pupa and nine adults of *O. insularis*.

At Kahani plantation a piece of coconut trunk with the exterior decayed contained five L1, three L3 (of which two were prepupae), six pupae and ten adults of *O. insularis*.

Some 48 *Oryctes* L3 were examined, and all were of healthy appearance; four were dissected, but none had any nematodes in the fermentation chamber.

Some 17 adults of *Oryctes* (16 O. *insularis*, one *O. simiar nesiotes* Paulian male) were dissected and the results are presented in Table VII. Three of

TABLE VII. *Distribution of nematodes in adults of* O. insularis *collected on Anjouan and Mayotte, Comores*

Island	No. males dissected	No. females dissected	No. males with nemas in aedeagus	No. females with nemas in bursa	No. females with nemas in colleterial glands	No. both sexes with nemas beneath elytra at base
Anjouan	12	4	6	2	4	0
Mayotte	12	5	3	0	4	0

the females had the ovaries small and undeveloped, and of these two had nematodes in the colleterial glands. One female had a total of 18 large eggs in the oviducts, another had 15 large eggs; both had some small nematodes in the colleterial glands but none in the bursa.

Development of the ovaries of *O. gigas*

Discussions with agricultural extension officers and plantation managers indicate that on the north-west coast of Madagascar the heaviest attack by *Oryctes* occurs in the rainy season (November to April). This would indicate that the adults of *Oryctes* were most active during this period.

At Ankivanja, females of *O. gigas* were collected and dissected in July, August and September and the results are given in Table VIII.

TABLE VIII. *Development of the ovaries of females of* O. gigas *at Ankivanja*

Date 1966	No. of females with ovaries small and undeveloped	Number of females with the following numbers of large mature eggs in the ovaries					
		3	7	9	19	21	22
12.vii.	1	1	—	1	—	—	—
4.viii.	2	—	1	—	—	—	—
2.ix.	3	—	—	—	1	2	1

In July and August, in mid dry season, the females of *O. gigas* found in the tops of dead standing coconut palms may have emerged only recently from metamorphosis and their ovaries would consequently be undeveloped. As the season progresses, more and more eggs would mature in the ovaries, ready for laying in the oncoming rainy season (November) as suggested by the trend in Table VIII, when females would fly to palm crowns to feed and to decaying logs to breed, with the resultant increase in activity during the rainy season already noted.

Discussion

It was noted in Madagascar that tall, isolated, or otherwise conspicuous coconut palms were often more severely attacked by *Oryctes* than shorter palms nearby. However, where only younger palms are available in an *Oryctes*-infested area, these too are liable to be attacked. Cumber (1957) commented on the ragged appearance of palms about villages in Western Samoa and noted the habit of beetles of congregating on isolated palms. He also noted that in plantations containing palms of two different ages, the older taller scattered palms are much more severely attacked than the younger ones beneath. Wood (1964) considers that beetles fly to the silhouette of a palm against the night sky, so that an exceptionally tall palm may be attacked while those of normal height in the stand around it are untouched.

The different species of *Oryctes* in Madagascar seem to have different behaviour patterns, for *O. pyrrhus* will attack coconut seedlings and young oil palms by burrowing in the soil, whereas adults of *O. simiar* were mostly found feeding in the hearts of established coconut palms.

The rarity of *Oryctes* in the forests of Madagascar may perhaps be due to the undergrowth obstructing the flight of the beetle. Both Cumber (1957) and Gressitt (1953) considered undergrowth to be important in restricting adult flight. Cumber concluded that the beetles seek unhampered flight conditions, so that beetles breeding away from plantations tend to gather and cause severe damage on the margins of the coconut plantations, and that beetles bred within plantations tend to fly towards margins or openings.

The occurrence of eggs, larvae (all stages) and adults of *O. gigas* in the tops of dead standing coconut palms on the north-west coast of Madagascar (see Table II) is curious, and can be explained by assuming either that *O. gigas* breeds all year round, or that some of the stages in the life cycle (for example, the third larval instar) undergo slow development over a prolonged period so that the whole life cycle occupies more than a year, and perhaps even two or three. Such slow development in *O. gigas* might be geared to the marked wet and dry seasons prevailing in the area, and would be very different from that of *O. rhinoceros*, which in Western Samoa occupies under favourable conditions approximately 130 days from oviposition to adult emergence (Hinckley, in press).

Oryctes gigas is a common pest of coconut palms in Senegal, the Congo Republic, Mozambique (Oberholzer, 1964), and on the north-west coast of Madagascar, where the southernmost records of its occurrence are given by Paulian (1959) as Soalala on the coast and near Maevatanana further inland. He considered this as evidence suggesting a relatively recent introduction of this species from Africa. The present author found specimens of *O. gigas* at Morondava on the central west coast, about 450 km. to the south of Paulian's southernmost records. This species has never been reported from the east coast of Madagascar. In February 1967, Mr. P. Monsarrat of Centre O.R.S.T.O.M. (personal communication) found an adult of *O. gigas* in a decaying trunk of *Medemia* near Ilakaka in the Massif d'Isalo. This indicates that the species has spread well into the interior away from the coconut palms on the west coast, and is feeding on other palms. However, there are no *Medemia* or other palms between the Isalo and Ihosy on the edge of the Central Plateau and the climate becomes colder with increasing altitude, so it is doubtful whether *O. gigas* will be able to spread overland further eastwards to reach the east coast.

The factors limiting populations of *Oryctes* in Madagascar are problematic. Scoliid cocoons were found in many widely separated localities, but they were never abundant in any particular locality. Lepointe (1960) also encountered Scoliids practically everywhere, but found that the percentage of larvae of *Oryctes* attacked was very small. Coquerel (1855), however, considered that

Scolia oryctophaga Coquerel exerted a significant control over the populations of *O. simiar* on Isle Sainte Marie. D'Emmerez de Charmoy (1923) and Simmonds (1941) collected Scoliid adults from flowers around Tamatave and on Isle Sainte Marie, but gave no information on the degree of parasitism of local populations of *Oryctes*.

The gregarine disease was found in several localities, but affected only a very small number of larvae. As far as fungal parasitism is concerned, cases of *Metarrhizium* were rare, while *Cordyceps* was found in only one locality.

No insect parasites of the adult stage of *Oryctes* were found.

It would seem that the major factor limiting populations of *Oryctes* in Madagascar is the number of suitable breeding sites available. In localities such as Ankivanja, where the amount of coconut wood or other rotten wood in a suitable state of decay is small, the population of *Oryctes* is restricted, whereas in areas such as Mahilaka, where material suitable for breeding is abundant, more *Oryctes* may develop.

The problem of *Oryctes* incidence in the Comores Archipelago is interesting, as there are very many coconut palms of medium to tall height present, and *Oryctes* larvae and adults of *Oryctes* are readily found in decaying trunks, yet the coconut palms in general do not appear to be heavily attacked or destroyed by these beetles. Here again the restricted number of available breeding sites appears to be the factor limiting population growth.

Summary

In a study of the incidence of damage to coconut palms in Madagascar and the Comores Archipelago caused by species of *Oryctes* (Scarabaeidae) it was found that attack is heaviest in localities where there are abundant breeding sites for the beetle, and that tall palms are more often attacked than short ones. The most important larval breeding sites are dead standing coconut palms and decaying coconut trunks and stumps. Larvae also breed in decaying satra trunks (*Medemia* sp.), wood of *Albizia* in coffee plantations, decaying Raphia trunks, and occasionally in rubbish heaps and manure, but are only rarely encountered in decaying wood in forests. Coconut palms are important feeding sites for *O. gigas*, *O. blucheaui* and *O. simiar*. *O. pyrrhus* attacks coconut seedlings and young oil palms. Forest palms are occasionally attacked. *O. ranavalo* attacks bamboo on the east coast. Banana plants are occasionally attacked by *O. simiar*.

Scoliid parasites of the larvae of *Oryctes* are widely distributed but not commonly found. Gregarines in larvae are also widespread but of rare occurrence. Oxyurid nematodes were often found in the fermentation chamber at the gut of *Oryctes* and Cetonid larvae. The fungus *Cordyceps* sp. was found at only one locality where it was attacking 56 per cent. of the larvae of *Oryctes*. Examples of infection by the fungus *Metarrhizium* were rarely encountered. Nematodes often occurred in the aedeagus of adult males of *O. gigas* and in the bursa copulatrix and colleterial glands of adult females, as well as under the elytra. They were less common in the other species of *Oryctes* examined. Mermithid nematodes were found in adults of *Oryctes* on rare occasions. No insect parasites of the adult stage of *Oryctes* were found. Elaterid larvae, possibly predacious on those of *Oryctes* were occasionally found but did not appear to be of much importance.

It is concluded that the major factor limiting *Oryctes* populations in Madagascar and the Comores is the number of suitable breeding sites.

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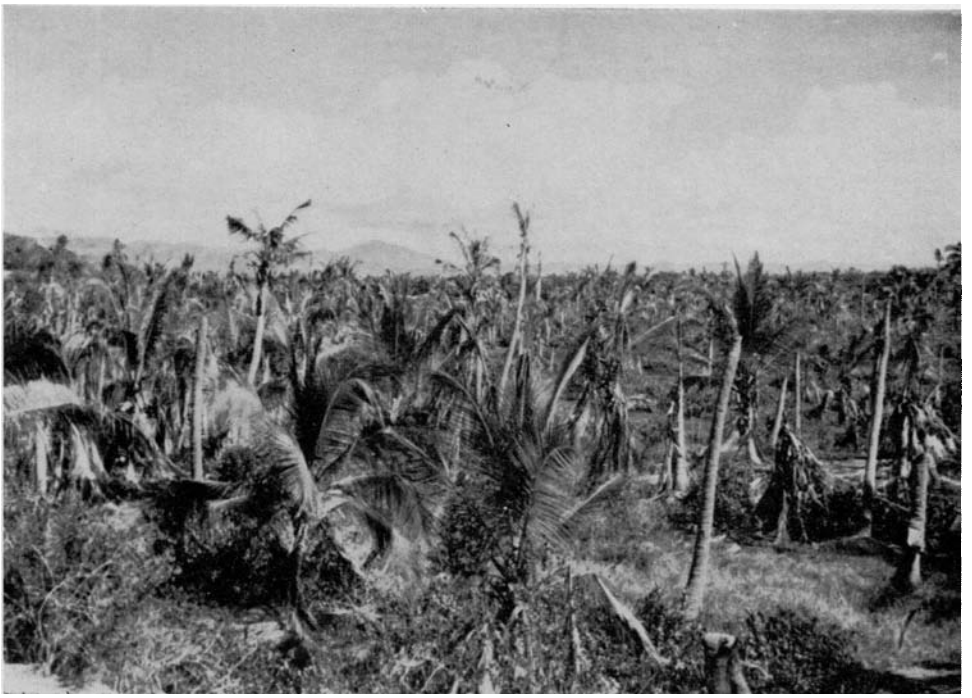

FIG. 1. Coconut plantation destroyed by *Oryctes* at Mahilaka on north west coast, with numerous dead standing palms.

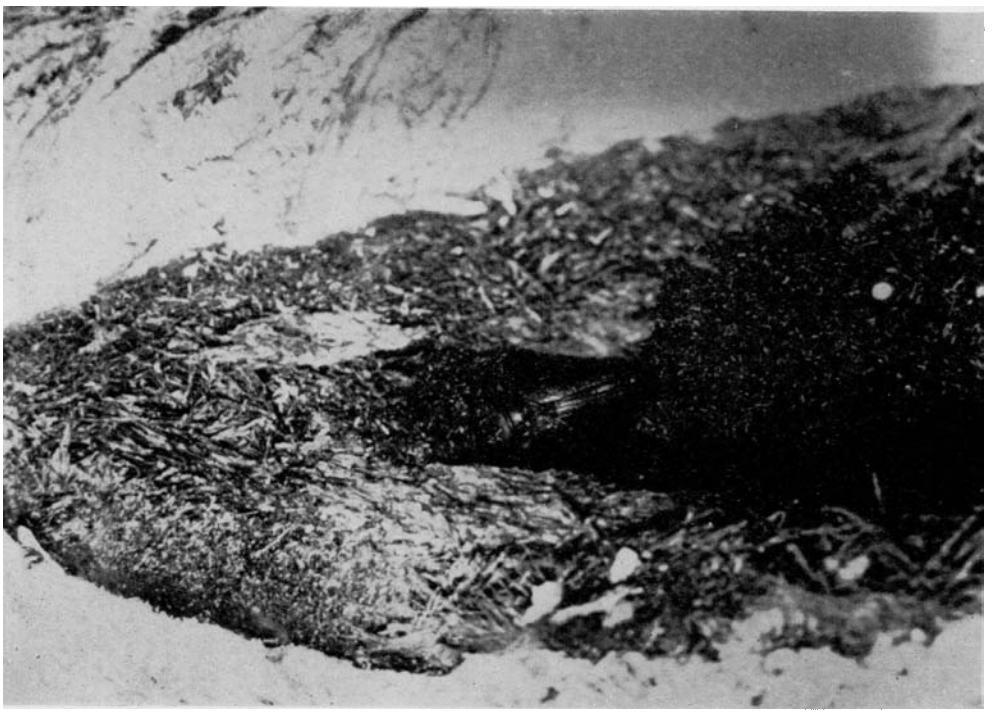

FIG. 2. Top of dead standing coconut palm at Ankivanja split open to show *O. gigas* adult and egg in central hole.

FIG. 1. Numerous *Oryctes* larvae (probably *O. gigas*) in central hole in dead standing coconut palm near Marovoay on west coast.

FIG. 2. Adult of *O. pyrrhus* burrowing in soil to attack base of young oil palm at Ambariomiambina on north east coast.

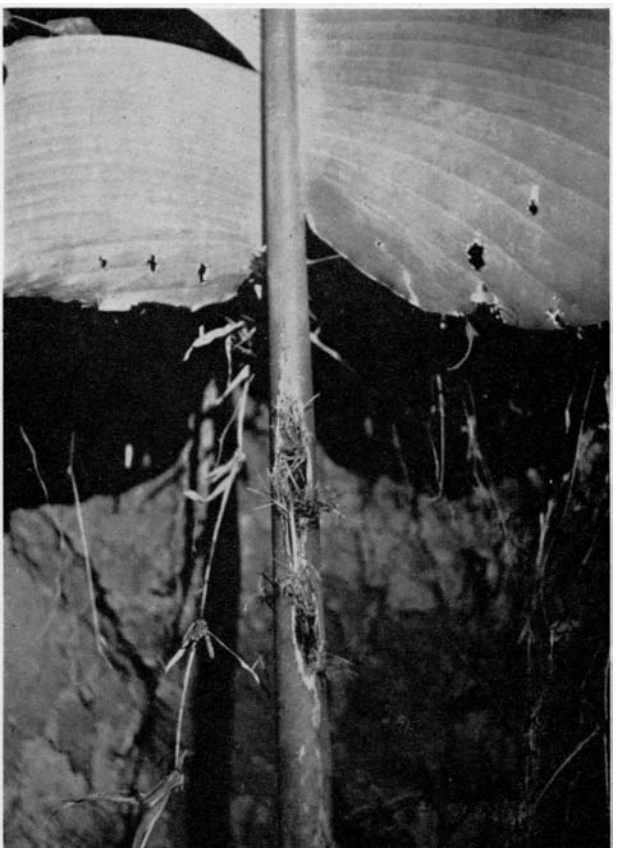

FIG. 1. Hole in midrib of frond of *Ravenala* palm at Kianjavato made by *Oryctes*.

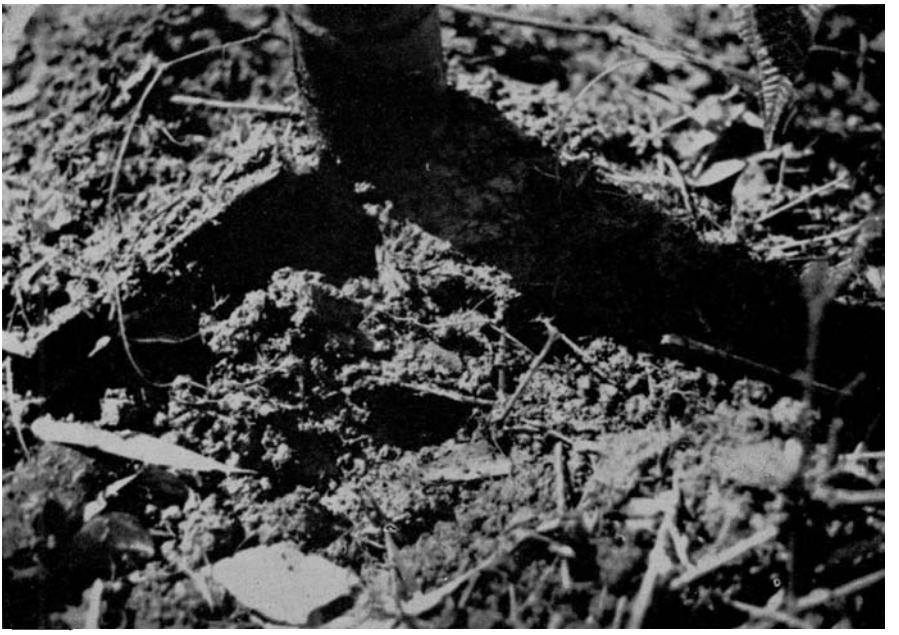

FIG. 2. Three burrows in soil at base of bamboo plant made by *O. ranavalo* at Kianjavato.

Oryctes larvae destroyed by *Cordyceps* fungus in decaying coconut log at Antsiraikiraiky on Isle Sainte Marie.