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The Coconut Rhinoceros Beetle Oryctes rhinoceros (L)[Coleoptera: Scarabaeidae: Dynastinae]

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The Coconut Rhinoceros Beetle *Oryctes rhinoceros* (L)[Coleoptera: Scarabaeidae: Dynastinae]

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The coconut rhinoceros beetle, (*Oryctes rhinoceros* (L.)), is one of about 42 described species of *Oryctes*, the majority of which occur in Africa. The largest concentration of species is found in Madagascar and nearby islands where Paulian (1959) recorded 13 species.

The majority of species feed on palms as their preferred hosts and several are serious pests of oil, date, areca, sago and coconut palms.

O. rhinoceros is primarily a pest of coconut palms but a wide range of wild and cultivated palms is also attacked. Less frequently, other crops including banana, sugar cane, papaya and pineapple are attacked.

Distribution

It is generally accepted that *O. rhinoceros* is endemic to the coconut growing regions of Asia, from West Pakistan, eastwards through India, Ceylon, Burma, Hainan, Hong Kong, Formosa and the Malaya Peninsula, the islands of Celebes, Ceram and Amboina in Indonesia to the Philippine Islands. (Fig. 1).

Oryctes rhinoceros posed on dissected growing point of coconut palm. ***Photo:*** K. J. Marshall.

*Joint United Nations Special Fund and South Pacific Commission Project for Research on the Control of the Coconut Palm Rhinoceros Beetle in the South Pacific Region.

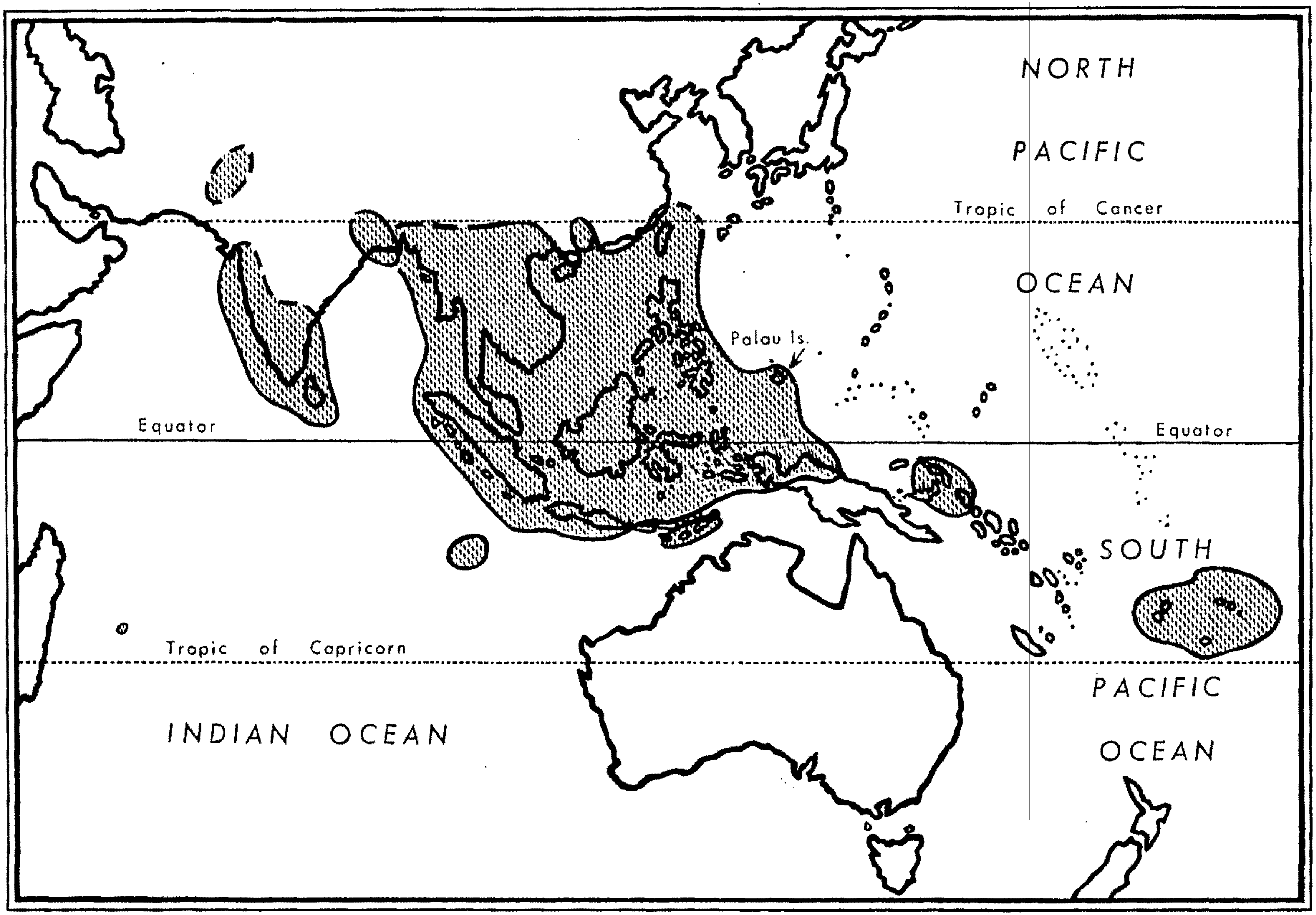

Fig. 1. World Distribution of *Oryctes rhinoceros.*

Outside this region it has been introduced to a number of copra producing areas of the Pacific and Indian Oceans. It is believed to have been introduced in *Hevea* seedlings from Ceylon to the Pacific to the island of Upolu, Western Samoa in 1909 from whence it spread to the neighbouring island of Savaii and to Tutuila in American Samoa. In 1921, the beetle was recorded from Niuatoputapu (Keppel) Island in the Kingdom of Tonga but it was successfully eradicated in a campaign directed by Mr. M. Müller from 1922 to 1930 (Müller, Pers. comm. 1965). Wallis Island, about 200 miles to the west of Samoa next became infested in 1931 (Cohic 1950). With the Second World War, there was an increase in aircraft and shipping activity in the Pacific region and abundant breeding sites were provided in war-damaged palms. During this time the beetle was introduced to Palau Islands, c. 1942; New Britain, 1942; and West New Guinea (date unknown).

After the war further establishments were recorded in Vavau (Tonga), 1952; New Ireland, 1952; Viti Levu (Fiji), 1952; Pak Island (New Guinea), 1960; Tongatapu (Tonga), 1961; and Tokelau Islands, 1963. (Fig. 2).

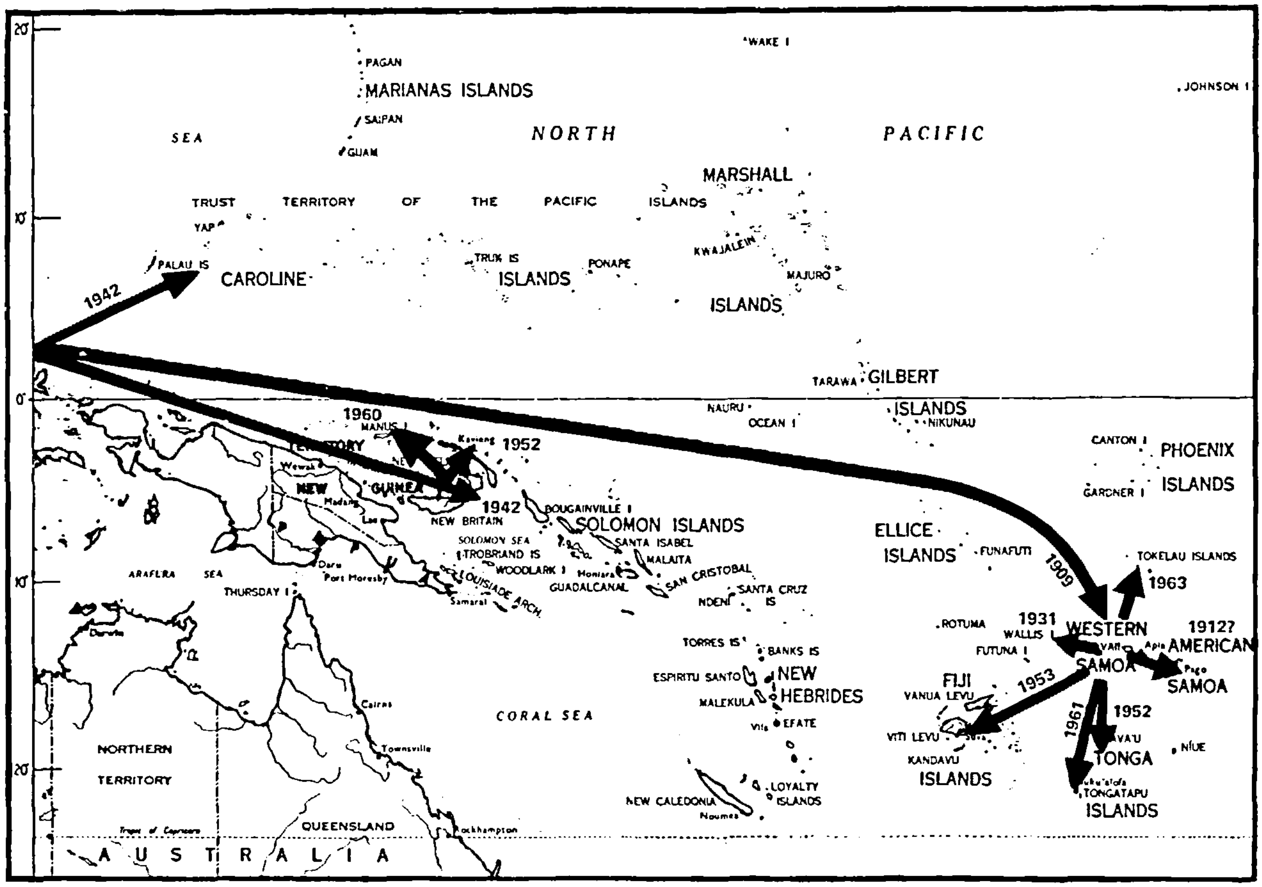

Fig. 2. Distribution and probable spread of *Oryctes rhinoceros* in the South Pacific Region.

In the Indian Ocean, the island of Diego Garcia was infested during the First World War presumably by beetles carried on troopships (Orian 1959). This was followed by the collection of specimens in the Cocos (Keeling) Islands by Dr. C. A. Gibson Hill in 1940 who lodged the specimens in the British Museum. Vinson (1963) next recorded its presence in Mauritius in July, 1963 and suggested that it was introduced by shipping.

Life cycle

The life cycle of the beetle is very well known. Eggs are laid in decaying organic matter where the larvae feed and complete their development. Favoured breeding sites are decaying coconut trunks and other logs, and heaps of sawdust, compost and cattle dung. At temperatures ranging between 20° - 30°C and with ample food, the egg stage occupies about 12 days and the three larval instars approximately 10 to 14, 12 to 18 and 90 to 120 days, respectively. There is a non-feeding prepupal stage of some 8 days and a pupal period of from 23 to 28 days. Unfavourable climatic or nutritional conditions delay larval development which may be extended up to 14 months and smaller than average sized beetles may be produced. The larva pupates in a cell constructed by excavating, if in a log, or by compacting the feeding media, if in friable material such as sawdust or compost. Sometimes larvae may also leave a feeding site to pupate in the earth, and pupae have been found as far as 150 cm under the ground.

Adult beetles live for up to six months, during which time they move between breeding sites for mating and egg laying, and feeding sites in the crowns of palms or on other host plants.

Both sexes mate several times and from studies of spermatophore residues in the ***bursa copulatrix*** of field collected females Hoyt (undated) estimated that there is a maximum of eight matings. However, field collected females have produced fertile eggs up to 130 days after being confined singly in cans of rotting sawdust which suggests that multiple matings are not essential. Egg production varies considerably depending on the longevity of the beetle and the suitability of the oviposition medium. Menon and Pandalai (1958) recorded up to 152 eggs per female although 90 - 100 would be more usual.

Rhinoceros beetles are nocturnal creatures, sheltering in the feeding and breeding sites during the day and flying in the hours between dusk and dawn. Despite their large size and conspicuous appearance they are rarely seen flying in plantation areas. There is a number of conflicting reports regarding their flight behaviour. Kalshoven (1951) mentions flights of about 50 metres as normal with a potential of several hundred metres. Menon and Pandalai (1958) state that the beetle is incapable of extensive flight and flight range is restricted to within 200 yards of its breeding place. O'Connor (1957) recorded that three rhinoceros beetles had flown to lights aboard a ship anchored 750 yards from land in Apia harbour. Hinckley (1967) demonstrated under laboratory conditions a flight potential of two or three hours for fully fed beetles tethered on lightweight lines. It would seem, therefore, that under favourable conditions with an abundance of feeding and breeding sites short flights are more usual; longer flights are resorted to only under adverse conditions.

Damage to palms

The larvae are generally innocuous although they have been known to damage timber posts and stumps set into the ground.

Adult beetles feed at the crowns of palms by boring through the petiole bases into the central unfolded leaves. The tissues are macerated and the extracted juices are ingested leaving a fibrous frass which is pushed out through the feeding hole where it lodges as evidence of beetle activity within.

Attacked palms present a typical appearance with accumulations of frass, holes or breaks in petioles and notches cut in leaf margins produced by beetles chewing on the unfolded leaflets (Fig. 3). Sometimes the immature spadix at the base of the frond is damaged thereby directly causing a reduction in the yield of nuts. If a beetle bores down to the meristematic tissue, it may destroy the growing point and consequently the palm will die, but this is not usual in bearing palms unless attacks are very heavy. Young palms with a small crown are much more likely to have their growing points damaged or destroyed.

Following beetle attack, palms are exposed to secondary infections from bacteria, fungi or insects. The secondary damage inflicted by palm weevils (***Rhynchophorus*** spp.) wherever they occur in Asia and New Guinea is generally of far more consequence than rhinoceros beetle attacks.

Economic losses

It is extremely difficult to assess the total cost of rhinoceros beetles to copra producers in Asia and the Pacific Islands since several component costs are involved. The first and most obvious one is the reduced yields reflected by lowered copra production. To this must be added the cost of control measures which include additional cultural practices which would not have to be undertaken in the absence of the beetle. Plantation establishment costs are increased when re-planting must be undertaken to replace young palms destroyed by beetles. The cost of quarantine procedures designed to limit the spread of the beetle is considerable even in uninfested territories.

Fig. 3(a) Frass produced by rhinoceros beetle feeding in coconut palm.

Fig. 3(b) Coconut palm petiole holed by rhinoceros beetle attack.

Fig. 3(c) Coconut palm showing marginal notches on fronds resulting from rhinoceros beetle attack.

Gressitt (1953) reported that the beetle killed one half of the palms in the Palau Islands within ten years of its introduction, but this was an extreme situation where there were few natural enemies and an abundance of breeding sites in palms killed by war activity.

Menon and Pandalai (1958) estimated that in India, at least ten per cent loss in yield is directly attributed to beetle damage to spathes and it is even higher than this in Assam and the Andaman Islands.

In Diego Garcia, Orian (1959) states that about one third of the coconut seedlings planted are killed by ***O. rhinoceros.*** Hinckley (1966) surveyed palms in several Pacific Island Territories and found an inverse relationship between beetle damage as indicated by cut fronds and the number of full-sized nuts per palm with crop reduction ranging from 0 to 60% as the average number of cut fronds per palm rose from 15 to 100%.

Estimates of the annual cost of rhinoceros beetles to South Pacific Territories exceed $U.S.1,100,000. Several of the estimates for individual territories are presented in Table 1.

TABLE 1

*ESTIMATES OF COST OF *O. RHINOCEROS* TO SOUTH PACIFIC TERRITORIES 1968

$ U.S.

Territory	Loss in Copra Production	Cost of Control Measures	Cost of Quarantine Procedures	Additional Plantation Estab. Costs	Total
American Samoa	$ 60,000	$ 7,000	$15,000	$70,000	$162,000
Fiji	$ 1,130	$113,000		-	$114,130
Gilbert and Ellice Islands	-	-	$ 800	-	$ 800
Kingdom of Tonga	$ 76,800	$17,143	$ 4,286	$96,429	$194,658
Trust Territory of the Pacific Islands	$ 75,000	$35,000	$ 1,000	$15,000	$126,000
Western Samoa	$576,000	$ 16,255		-	$592,255

*Estimates compiled with the assistance of Territorial Departments of Agriculture

Control

Investigations into methods of controlling ***O. rhinoceros*** have been undertaken for more than half a century with extremely variable results. In 1963, a five year Project supported by the United States Department of Agriculture under U.S. Public Law 480 was initiated through the Indian Central Coconut Research Committee to investigate methods of controlling the pest in India. The following year a separate Project financed jointly by the United Nations Special Fund and the South Pacific Commission was established to undertake similar research in the South Pacific Region. The research findings of both these Projects have been freely drawn upon in the preparation of this article.

Control can be directed at either the larval or adult stage of the life cycle. Over the years many methods of control have been developed which can best be considered under the separate headings of cultural, chemical and biological methods.

Cultural control

The destruction of breeding sites is of prime importance in any control programme. This was borne out in the only successful eradication campaign waged against the beetle, on the small island (six square miles) of Niutoputapu in the Kingdom of Tonga where the major effort was directed at the destruction of potential breeding sites. Supporting legislation was enacted to compel all adult males on the island to provide free labour for this work. In 1930, nearly eight years after its discovery, the beetle had been eradicated.

In India and Ceylon, the most important breeding sites are in cattle dung heaps and pits. In South East Asia, decaying logs and sawdust are favoured breeding sites while in the South Pacific islands most of the breeding is in decaying logs with some in sawdust, compost and village rubbish heaps.

Where dung heaps and pits are essential for the maintenance of agricultural systems, they should, ideally, be covered or screened to prevent beetles gaining access but this is too costly in most cases, so an alternative is to turn them at regular intervals and remove any *Oryctes* larvae. Sawdust can often be burnt or it may be thinly scattered so that heaps are not allowed to accumulate. All too frequently in control campaigns, sawdust heaps are left to become bountiful breeding sites from whence rhinoceros beetles are literally 'harvested' each time the heaps are searched, when for a fraction of the effort which goes into searching for the beetles the heaps could be permanently destroyed.

Log disposal presents considerable problems, particularly where any large scale agricultural development is occurring either in clearing land or destroying old palms in replanting schemes.

Where logs can be stacked and dried they may be burnt. This, however, is not possible in areas which do not have a pronounced dry season. In Western Samoa, logs which cannot be burnt are disposed of by casting into the sea, (Fig. 4.).

Fig. 4. Coconut palm trunks disposed of by casting into the sea in Western Samoa.

On large estates in Malaysia, logs are sometimes buried out of reach of ovipositing beetles. This method of disposal is extremely costly and suitable only for large scale plantation operations.

Where logs cannot be effectively disposed of, they may be rendered less productive as breeding sites if they are screened by vegetative barriers. Experiments conducted in Malaysia and Western Samoa showed that beetle breeding was greatly reduced in logs hidden by grass or leguminous cover crops.

There is also strong evidence that forested areas present a physical barrier to the flight of beetles so that breeding sites in those situations are not utilised. In the successful eradication campaign on Niutoputapu, forested areas were ignored when potential breeding sites were destroyed.

Apart from the destruction of breeding sites, the collection of adult beetles is sometimes resorted to as a control procedure. Beetles can be extracted from palms by impaling them on a barbed spike made from rigid iron wire inserted into the tunnels made by feeding beetles.

Beetles can also be hand collected from traps made from sections of coconut logs split longitudinally and laid in rows on the ground, (Fig. 5.). Beetles attracted to these sites for mating and oviposition can be collected if the traps are inspected every two or three days. Sometimes, however, these 'traps' themselves become breeding sites for beetles when they are not searched thoroughly and eggs are not removed or destroyed.

Fig. 5. Inspection of split coconut log trap.

Chemical control

Chemical control measures can be directed at both the larvae and adults, but in both cases the cost of labour and insecticides may be limiting factors in their adoption as general procedures.

Crown treatment of palms using a 1 : 9 mixture of 6.5% gamma isomer BHC dust and sawdust applied to the topmost five axils affords the palm good protection against beetle attack for up to six weeks. However, this treatment does not greatly reduce the number of beetles within an area and it seems that the protection is due to the repellent effect of the insecticide. Consequently adjacent untreated palms may be more liable to be attacked by beetles repelled from treated palms. Young palms which suffer most from beetle attacks can be relatively easily treated in this manner but the cost of treating mature palms is prohibitive when climbers have to be employed.

O'Connor (1953) found BHC and lindane to be more toxic than dieldrin against adult beetles in treated compost and in a further series of experiments, diazinon wettable powder was more effective than

BHC, producing a quicker 'knock down' effect and having an effective residual life of up to 156 days in field exposed sawdust mixtures.

Mariau (1967) conducted similar experiments on an African species of rhinoceros beetle, *O. monocero* Ol., in which beetles were exposed to insecticide sawdust mixtures. Diazinon was clearly superior to chlordane, dieldrin, heptachlor and lindane in laboratory tests, but in field experiments, sawdust with BHC and lindane proved more effective and more persistent than diazinon granules and sawdust. BHC was also phytotoxic to young coconut palms.

In laboratory screening experiments, Stelzer (1968) found both diazinon and furadan to be more effective than either dieldrin or carbaryl in spray applications against larvae and adults of *O. rhinoceros.*

The treatment of beetle breeding sites with insecticides is a practical proposition only in those situations which are artificially created, e.g. sawdust heaps, compost pits and possibly in fallen tree trunks and coconut trunks produced by replanting or land development projects. Log and trunk treatment by spraying or injection techniques has not proved successful.

In the South Pacific Region several coconut replanting schemes are either contemplated or already under way to replace those senile unproductive palms planted 50 to 80 years ago by the early European settlers.

The threat to the young replants from beetles breeding in the dead trunks of the old palms is considerable and replanting costs would be greatly reduced if the trunks could be effectively poisoned so that disposal is not necessary. Experiments now being conducted by the U.N./S.P.C. Project are designed to develop a method to incorporate insecticides with silvicides used to thin out senile palms. An additional benefit would be obtained if the poisoned palms retained their attractiveness as oviposition sites for female beetles but did not permit larvae to complete their development.

Treatment of breeding sites in sawdust, cowdung and compost does not present undue practical difficulty provided there are no associated toxicity hazards. In many Pacific Islands, domestic poultry and pigs are frequent scavengers in compost pits and they are sometimes killed following insecticide applications.

Insecticide screening trials undertaken by the P.L. 480 Project in India indicated effective kills of third instar larvae for up to six months after treatment of cowdung with 0.1% BHC, telodrin and aldrin. Under the same conditions 0.1% carbaryl produced 92% mortality after seven days but after one month it was reduced to 50%. Under field conditions where weathering is more severe one would expect the residual effect to be somewhat less. Spathe attack was reduced from 132 to 6 per 554 sample palms over an 18 months period in an area where all dung breeding sites were sprayed four times per year with 0.01% carbaryl (Kurian, 1967).

Included amongst chemical control methods currently being investigated is the search for attractant chemicals. Generally these may be regarded as either sex or feeding attractants. The existence of a sex attractant has not been demonstrated but data collated in Western Samoa by Hinckley (1967) showed that the incidence of sexually mixed groups of beetles in breeding sites was significantly higher than one would expect if aggregations were formed by chance encounters.

Conventional methods of screening attractants by exposing insects to the candidate chemicals in olfactometers or cages have not proven successful with *O. rhinoceros.* The nocturnal habits of the beetle together with its large size and clumsy flight, even in very large field cages, make it difficult to conduct experiments which will yield consistent results.

Within the U.N./S.P.C. Project, a number of chemicals which have shown promise as attractants for scarabaeid beetles in the United States have been supplied by the United States Department of Agriculture for screening in direct field exposures to natural populations of the beetles. Of several compounds which have exhibited attractant properties, chrysanthemumic acid and some of its derivatives seem to hold most promise (Barber 1967).

Biological control

Over the years, biological control measures have been widely investigated. Searches for parasites, predators and diseases of *O. rhinoceros* have been undertaken throughout its range of distribution and in places where related species of dynastid beetles occur.

A number of useful parasites and predators has been found, and introduced to many areas. Of the few species which have become established anywhere, the parasitic wasp, ***Scolia ruficornis*** F., from Zanzibar has proved to be the most effective controlling factor. It has readily adapted to ***O. rhinoceros*** in many countries but its activities are restricted to loose friable material, such as sawdust heaps, compost and the frass produced by decaying logs. Unfortunately it does not enter into the firm logs, which are the main breeding sites of ***O. rhinoceros*** in many Pacific Islands. Under favourable conditions, parasitism rates up to 30% have been recorded in Western Samoa, where ***S. ruficornis*** has been established for some twenty years. (Fig. 6.).

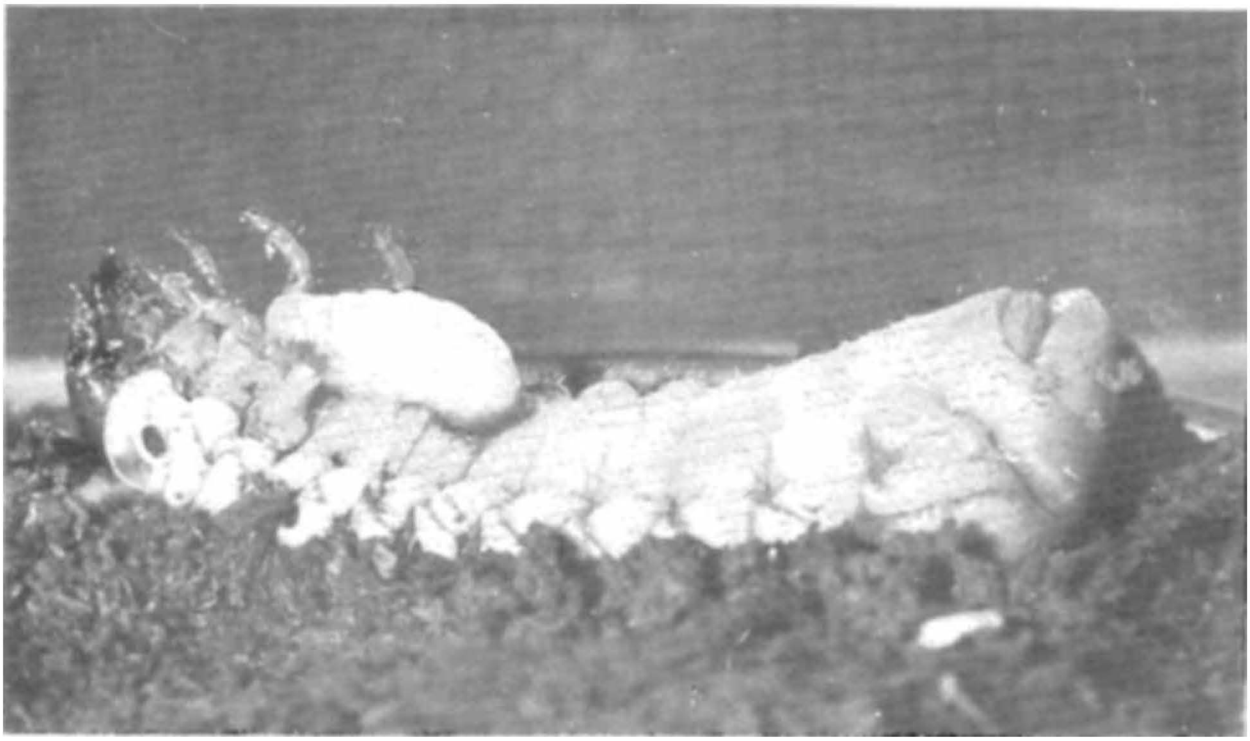

Fig. 6. Third instar ***O. rhinoceros*** larva parasitised by ***Scolia ruficornis*** larva attached to central surface of abdomen.

Several insect predators have become established following their introduction but they have proved to be relatively ineffectual controlling agents. They are mostly general feeders and the most that can be hoped for is that they will occupy ecological niches which will favour their chances of coming into contact with ***O. rhinoceros.*** However, the cumulative effect of several predators operating in their own separate spheres may be sufficient to control the pest to the extent that it is of lesser economic importance.

In 1955, two click beetles, ***Alaus speciosus*** L. and ***Lanelater (Agrypnus) fuscipes*** (Fabr.) were introduced to Western Samoa and became successfully established (Hoyt and Catley 1966). The larvae of both species are predatory and they are capable of killing even the largest third instar ***Oryctes*** larvae. ***Alaus*** larvae have been found mostly in tunnels in decaying logs particularly associated with ***Olethrius insularia*** Fairm. (Coleoptera : Cerambycidae) in kapok although it has also been found associated with ***Oryctes*** larvae in a standing dead coconut trunk about nine metres tall. An adult ***Alaus*** was found nearby on the trunk of a living palm.

Lanelater larvae are more closely associated with ***Oryctes*** larvae, being found in the frass produced from decaying logs, in sawdust heaps and on the ground under logs. For this reason it is considered they are more effective ***Oryctes*** predators.

At Kayangulam, India, the P.L. 480 Project is investigating predators of *O. rhinoceros* and one of their most promising is the carabid beetle *Pherosophus sobrinus* Dej. which is commonly found associated with *Oryctes* larvae in pits and heaps of cow dung.

This species was introduced to Fiji, Tonga and Wallis Island in 1962 (O'Connor 1964) and to Mauritius in 1965 where field recoveries have since been made.

Two predators of *Oryctes* adults have also been tried in biological control experiments. They are the carabid beetle, *Neochryopus savagei* Hope, introduced from Nigeria to New Britain, Fiji, Tonga and Samoa (Catley 1963) and the reduviid bug, *Platymeris laevicollis* Dist.* which has been introduced from Zanzibar to New Britain, Fiji, Tonga, Samoa and the Solomon Islands in the South Pacific and to Malaysia, India and Ceylon where it is being reared for field releases against *O. rhinoceros.* Establishment of *P. laevicollis* has been confirmed in Western Samoa (Catley 1968) and the Solomon Islands (Greenslade 1968) and field recoveries without evidence of establishment have been made in New Britain and Fiji.

Many vertebrate animals have been recorded as predators of *Oryctes* larvae and adults throughout its range of distribution (Gressitt 1953; Hinckley 1967; Uchida 1966) but it is generally considered that none are significantly effective controlling factors and serious consideration has not been given to the use of any of them as biocontrol agents.

Currently being evaluated by the U.N./S.P.C. Project are mites (*Hypoaspis* sp.) found associated with eggs and newly hatched larvae of *Oryctes monoceros* Ol. in Ivory Coast. In laboratory experiments the hatching of eggs was reduced by some 78% in the presence of mites. (Mariau 1968).

A number of species of nematodes has been found associated with all developmental stages of *Oryctes* but their relationship to their hosts has not been determined. Of particular interest are nematodes (Angiostomatidae ?) which are frequently found in the aedeagal passages of males and in the *bursa copulatrix* of females. They have never been found naturally in *O. rhinoceros* but they have been found in all other species of *Oryctes* examined. Recently, with the co-operation of Dr. D. Mariau of I.R.H.O. Port-Bouet and Dr. B. Hurpin of Institut National de la Recherche Agronomique, La Minière, France, the nematodes have been successfully transferred to *O. rhinoceros* by cross mating with infested *O. monoceros* and the effect, if any, of the nematodes on the fertility and fecundity of *O. rhinoceros* is now being studied by the U.N./S.P.C. Project.

Associated with the search for parasites and predators has been a search for diseases of *Oryctes*. The green muscardine fungus *Metarrhizium anisopliae* (Metsch.) Sorokin, has been known as a pathogen of *O. rhinoceros* for nearly sixty years and it is probably the most important factor controlling *Oryctes*, particularly under conditions of high temperature and humidity. It is widely distributed and has been recorded from several species of *Oryctes*. A technique for the mass production of spores has been developed and field scale control experiments are being conducted by the U.N./S.P.C. Project.

In 1963, Dr. A. M. Huger discovered a diseased condition of *Oryctes* larvae in Malaya and referred to it as Malaya Disease. Subsequently a virus, *Rhabdionvirus oryctes* Huger, was isolated as the causal agent (Huger 1966) and a number of laboratory and field experiments with this organism have been undertaken and are continuing in the U.N./S.P.C. Project. In the same Project, gregarine infections of *Oryctes* larvae were found by Bedford in Madagascar (Bedford 1967; Tuzet et al 1967) and in Germany (Huger 1967). It would appear, however, that neither of the gregarines is truly pathogenic but they may have some deleterious effects on their hosts in extremely heavy infestations due to mechanical blocking of the coelom.

Included in the biological methods of control are autocidal methods involving the release of sterile male beetles into a population to lower the production of fertile eggs produced by females with which they mate.

Sterilization by irradiation and by chemosterilant compounds is being investigated. Working under contract to the U.N./S.P.C. Project, the Station de Recherches de Lutte Biologique et de Biocoenotique at La Minière, has determined the effective sterilizing dose of irradiation on male beetles to be 7,000 rads with an optimum dose of about 10,000 rads (Hurpin 1968).

Sterile male release programmes may be objected to because of the risk of raising the level of damage to palms in the release area, but there is some scope for control or eradication programmes on small

*Generally erroneously referred to in the South Pacific Region as *Platymerus rhadamanthus* Gerst.

islands if the existing males in the population can be lured to a trap with a powerful attractant, then sterilised either by irradiation or chemosterilants and released into the population.

One other approach to the control of *Oryctes* which has not yet received much consideration is the introduction of ecological homologues which could compete with *O. rhinoceros* for breeding sites. Many of the smaller Pacific Islands have a relatively poor insect fauna and there is a number of innocuous insects such as passalid and lucanid beetles which could be introduced to assist in the breakdown of logs which are major breeding sites. There might, in some cases, also be an added advantage if the imported ecological homologue was able to maintain and assist the spread of one or more of the already introduced diseases, parasites or predators.

De Bach (1964) has even speculated on the possibility of importing other pest species to displace a worse pest from its ecological niche. This offers interesting possibilities but it is difficult to imagine that other pest species of *Oryctes* or related coconut dynastids would ever be deliberately introduced for this purpose. It is, however, worthy of mention that in New Britain and New Ireland, *O. rhinoceros* has a narrower distribution where the indigenous coconut dynastids, *Scapanes australis grossepunctatus* Sternb., *Xylotrupes gideon* L. and *Trichogomphus semmelinki* Rits. occur, than in the smaller Pacific Islands where *O. rhinoceros* has little competition for breeding or feeding sites. However, other factors may be in operation in this situation and perhaps some of the biocontrolling factors of the indigenous species have adapted to *O. rhinoceros* to keep its numbers down. It is hoped that a clearer picture will be presented when ecological studies currently being undertaken in New Guinea by the U.N./S.P.C. Project are concluded in 1969.

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