Australia's tropical fruit industry is besieged by native fruit-piercing moths which attack at night and destroy whole orchards in hours. CSIRO entomologists believe exotic predators offer the best chance of long-term control. Tim Thwaites reports.

Sweet tooth

'One wet night I was introduced to the fruit-piercing moth, and was shown how to distinguish it from other moths. Since that night, I have never ceased to be in awe at the beauty, strength and tenacity of these creatures.

It was then that I had the first inkling of the damage that this insect was capable of unleashing. I have reared them from egg, learned much about their host plants, and have watched in wonder as they ravage the fruit in our orchard.'

These are the words of Bob Brown, who grows tropical fruit on a property about 80 kilometres north of Townsville in Queensland. He was speaking at an international workshop on fruit-piercing moths, which are a significant menace to tropical and sub-tropical fruit in Australia and the islands of the western Pacific. The workshop was held last year (1995) at CSIRO's Division of Entomology in Brisbane.

Fruit-piercing moths have mouthparts formed into a long, flexible tube or proboscis which has a hard, sharply-pointed and barbed tip. With this, the moths penetrate the firm skins or rinds of intact fruits (even citrus fruit and lychees) before they ripen, feeding on the fruit's sugars and breaching its defences. Through the small opening made by the moth's proboscis, other organisms such as fungi, micro-organisms and fruit-sucking insects can enter. Once these organisms arrive, the fruit rots and spoils quickly.

Whether fruit-piercing moths destroy fruit directly or indirectly is immaterial to fruit growers between Cape York in northern Queensland and the Clarence River region of northern New South Wales who have watched them take entire crops of lychees and mangoes in outbreak years. The moths are also a serious pest of other fruit, including carambolas (star fruit), persimmons, mandarins and paw paws, and attack stone fruit, longans, kiwi fruit and guavas.

Unlike many other important pests, fruit-piercing moths are home grown. The most damaging species are all members of the moth family Noctuidae and all native to Australia. That makes the problem of controlling them all the more difficult, for two important reasons.

Pictures: Don Sands, CSIRO Entomology

Main picture: Males of *Othreis fullonia* tend to predominate in orchards. Here a male is seen feeding on a lychee.
Insert: The proboscis of the piercing moths is heavily spined (right) compared with the non-piercers (left).

In the tropics, all five damaging species of the fruit-piercing moth can breed and feed year round.

Above: *Othreis fullonia* larvae vary in colour. They are usually black or occasionally green. Left: When larvae of *Eudocima salaminia* first hatch they are green.

First, there are concerns that any serious attempt to reduce the abundance of fruit piercing moths may upset the balance of the biological communities of which they are part. Second, because moth numbers are not controlled by natural enemies in Australia, any attempt to regulate them biologically would involve introducing new species to the country, a step to be taken with caution.

Biological control of a native pest is not easy, according to Dr Don Sands, a senior principal research scientist from the Division of Entomology. For the past eight years, Sands has led a group studying fruit-piercing moths in Australia, South-East Asia and the islands of the Western Pacific.

'In Australia, we have exacerbated the problem by providing the moths with high-quality food by growing crops of fruit,' Sands says. 'And we interfered with their breeding habitat by clearing it, and at times enhancing the growth of vines on which their larvae feed. Now, there is no stable population.'

It is that instability (the cyclical outbreaks of moths) that does the most damage.

'I would finish work late in the day, have an evening meal with the family, the necessary bath, catch up with the events of the day, a bit of TV, then later perhaps a short walk in the orchard. By that stage of the night, the damage was done, and the culprit gone, unseen.

We had a great deal of difficulty in explaining to bank managers that, while we were able to grow good quality fruit for market, something kept eating them in the middle of the night. Later, on being told that the culprit was some sort of moth, the response in most cases was one of mocking incredulity. We are still confronted with this response from farmers and non-farmers alike.'

Even Don Sands had difficulty in believing the damage caused by fruit-piercing moths. It was only after he visited Bob Brown's orchard in 1987, and collected members of almost all the Australian piercing species in one night, that he began to recognise the magnitude of the problem.

On the basis of painstaking field work, the research group now knows that most of the damage is done by five of the seven Australian species of fruit-piercing moth. The culprits are *Othreis fullonia*, *O. materna*, *O. jordani*, *Khadira aurantia* and *Eudocima salaminia*. In the tropics, all five species can breed and feed year round, though they become a problem to growers mainly in the wet season, from December to April, when the vines upon which the larvae feed are growing lushly.

In sub-tropical areas, south of Mackay on the central Queensland coast, only two species occur as pests (*Othreis fullonia* and *Eudocima salaminia*) and they are generally annual migrants. In the laboratory, the researchers have found that mating, feeding and egg laying do not occur at temperatures below 16°C. In the field this means that only in rare warm years does *E. salaminia* overwinter in sub-tropical regions, and *O. fullonia* never does.

More commonly, the two species travel south in about the third week of

Outbreaks of *Othreis fullonia* can result in complete crop losses, as seen here with citrus at Byfield in Queensland.

November, after a build-up in numbers in their tropical breeding grounds. The researchers think the moths probably hitch a ride on the prevailing north-westerly winds. Whatever the case, they regularly reach Lismore in northern New South Wales, and, on rare occasions, have been collected as far south as Canberra.

When the migrants reach their sub-tropical destinations, they breed actively until April or May. The migrant moths themselves usually do little damage, but the first generation of their offspring can be most destructive.

'The week that this first generation hits the crops,' Sands says, 'coincides with the time that the bulk of lychees ripen.' The results can be disastrous.

The moths fly into the orchards just after dusk. Within three hours, the damage is done. At present, the only sure way of combatting them is to cover fruit trees with fine nylon netting which reaches to the ground. But this is expensive, time consuming and labour intensive. The researchers have at least made the job easier by developing a model which helps predict when moth attacks are likely.

'Migration occurs after the populations up north build up to a threshold,' Sands says. 'Temperature is an important factor. But the timing of migration is also related to plant growth, survival over winter, rain and favourable winds.

'We have developed a simulation model which allows us to predict migrations of *E. salaminia* with a fair degree of accuracy. In normal years, the moths breed to hit the south-eastern crops about 40 days after migration begins.'

Growers depend on nets because insecticides are of little use in preventing moth damage. Surface poisons have little impact because the moths pierce the skin; they do not feed on it. The alternative, an insecticide which is absorbed into the fruit itself, cannot be used at a time when the fruit is about to be harvested for human consumption.

Researchers from the CSIRO group and at the Queensland Department of Primary Industries research station at Mareeba, just west of Cairns, have explored several other possible physical and chemical measures for controlling the moths, with limited success.

A group led by Dr Harry Fay working at Mareeba has shown that moth numbers can be reduced by illuminating orchards with yellow-green lights. But while moth numbers were reduced by more than 60%, the effect seemed limited to the genus *Othreis*. The researchers came to the conclusion that the technique was expensive for only modest reduction in damage.

Both research groups have looked at the possibility of using sex pheromones (external hormones) to attract and trap moths. So far neither group has managed to detect any chemical which can be demonstrated to affect the behaviour of the moths, Sands says, but more work needs to be done.

'We've only just found out the likely way some of the species produce pheromones,' he says. 'But this is expensive, sophisticated work and we have insufficient staff and equipment to pursue it at present.'

Sands says another attractant, fruit lures, can decrease damage by about one tenth, but the researchers as yet have come up with no lure stronger than the call of the ripening fruit. Given a choice, the moths will by-pass the lure for the real thing. So the lures can only work to reduce moth numbers in the weeks before harvest.

'Some fanciful ideas float around from time to time regarding the control of the fruit-piercing moth. Ideas such as smacking them down with tennis racquets or cricket bats, or doubling the dose of whatever chemical is the flavour of the month. I can think of better ways of using up all my energy than running around my orchard on a wet night belting up moths with a tennis racquet!

There are many of us who see a big future in Asia supplying high-quality fruit out of season. But all the likely

Damage to citrus fruit by piercing moths is followed by decomposition from invading bacteria and fungi.

products are targets of the fruit-piercing moth, and heavy losses by the pest will be difficult to bear.

The research must continue to its ultimate conclusion. That is the acquisition of the means to control the fruit-piercing moth as a major pest of our fruit crops. I do not believe that total elimination is possible or even desirable, but the ability to control this pest is an important step towards the development of a dynamic and progressive fruit industry in the north.'

The Papua New Guinean *Telenomus* is an important parasite, introduced into Fiji. Tonga and Western Samoa.

After eight years, Sands has come to the conclusion that the only long-term solution to the problem of fruit-piercing moths is biological control: introducing natural enemies of the moths from Papua New Guinea and Asia. In fact, in some ways he thinks this will be restoring a natural balance. He believes the reason the moths have few natural enemies in Australia and the western Pacific is that they have used their spectacular migratory ability to out-distance predators.

'Equivalent moths occur in Papua New Guinea and throughout equitorial South-East Asia, but their numbers are kept in check by egg parasites.' These parasitic wasps could do the same in Australia where they already have some close relatives, he says, .

Two research funding bodies and several fruit grower associations support this approach. The Australian Centre for International Agricultural Research (ACIAR) has provided more than $1 million over the past seven years for work on biological control overseas. This includes exploratory work in Papua New Guinea selecting the most effective predators and collaborative studies in the islands of the western Pacific, where the fruit-piercing moth *O. fullonia* has emigrated with devastating impact. With assistance from Sands and his team, several of the Pacific nations have begun to introduce the two parasitic wasps that have most potential, *Telenomus* and *Ooencyrtus.*

Last year's international workshop at Long Pocket was financed by ACIAR. Entomologists from three countries (Samoa, Tonga and Fiji) gave preliminary reports of the impact of the introduction of the two wasps. The news was encouraging. Already, it seems, the wasps are spreading and in Western Samoa have begun pegging back moth populations by about 2% a year.

But Australia is not just another Pacific island. The insect communities are more complex, and so are the quarantine regulations. The Rural Industries Research and Development Corporation (RIRDC) has granted the CSIRO research team about $120 000 in the past three years to study the prospects for

Above: Adult of Australian *Euplectrus* species, an uncommon tropical parasite of fruit-piercing moth larvae.
Right: Parasitised eggs of *Othreis fullonia.*

Tight security at the lab

Perhaps no-one is more aware than an entomologist working on biological control of the care which must be taken to ensure no foreign organisms are introduced to Australia accidently.

But if biological control of fruit-piercing moths is to be achieved, natural enemies will need to be introduced from overseas. To prove this can be done safely and without unacceptable disturbance to the local environment, tests must be carried out in Australia which bring together the local pests with their foreign enemies.

These tests can only be undertaken in high-security laboratories which are biologically isolated. At the CSIRO Division of Entomology at Long Pocket in Brisbane, the laboratory in which such work is carried out has double glazed windows and air locks for entry and exit. The air is recirculated, and workers must make sure that any material they take into the laboratory is sterilised by steam or fumigation (or incinerated) before emerging. The laboratory itself is certified by quarantine authorities every year.

But that's only the start. Even using such a facility, it is not easy to ensure against chance introductions of foreign species.

In the case of the New Guinea egg parasites, Don Sands says, a healthy year-round breeding colony of fruit-piercing moths had to be established first. 'We needed a continuous supply of eggs in which to rear the parasites,' he says.

Only then were the parasites themselves collected from the wild in New Guinea and brought in. The Australian Quarantine Inspection Service was notified and issued permits for importing the foreign species. The wasps were allowed to be unpacked only after they were safely inside the secure laboratory. All materials which arrived with them, particularly plant materials, were then put into an autoclave, a sterilising machine which uses high pressure steam.

The wasps had to be checked for parasites of their own, so that no unwanted travellers or diseases entered Australia on their bodies. Then the wasps were allowed to breed in the eggs from Australian moths. All the subsequent tests were carried out on their offspring raised in quarantine in Australia.

Initially, the researchers concentrated on discovering the best conditions under which to raise the foreign wasps: the optimum temperatures under which they survive and breed, the best light, the right food and the most comfortable humidity. 'We need to replicate the wild as best we can,' Sands says.

Finally, there are the tests on the interaction between the wasp parasites and the moths themselves: first, to see what it is that draws the wasps to the moth eggs to lay their own eggs inside; then, to see what species the wasps will attack, and how efficiently.

biological control in Australia. The group has used the money to conduct laboratory trials with the two parasitic wasps.

While studies had been proceeding quietly, recent events and publicity have thrown the whole question of biological control into the limelight.

'Following the papaya fruit fly outbreak in north Queensland, fruit growers are now taking greater notice of the work of entomologists, and have become vitally interested in the search for safe methods of control they can use without resorting to insecticides,' Sands says. 'It means we have to be meticulous in the preparation of our case for introducing the wasps.'

The case for introduction has to be made to the Australian Quarantine Inspection Service, the Australian Nature Conservation Agency and to various state government departments. It is a hard gauntlet to run.

'We need agreement from many reviewers and referees,' Sands says. 'Initially, about 20 people will go over the proposal with a fine tooth comb, then a stream of others will have a go at the submission and highlight anything which seems unsafe.'

Of major concern is the impact of the parasites on non-target organisms. Given that to be effective the natural enemies must keep in check five species of moths from three different genera, Sands will be concerned about parasite development on other, closely-related moth species. But he is not deeply concerned, with good reason.

Most of the other susceptible species are rare, he says. And because their eggs are few and far between, they are much less likely to suffer population depression.

'Cases of insect parasites wiping out their prey are extremely rare,' Sands says. That's not the way parasites work, because that way they would die out too.'

Larvae of an Australian *Euplectrus* parasite feed externally on a moth larvae. A related species, *E. maternus* from India will be studied as a possible biocontrol agent.

After success in the Pacific, Sands is confident that eventually he will be able to introduce the parasitic wasps into Australia. And he is even working on a follow-up, a larval predator from India. Already he is learning how to rear an Australian equivalent in preparation for the research that will go into preparing another case for introduction of an exotic species to Australia.

Meanwhile, now the Queensland drought seems to have broken, and the big wet is back in its rightful place, the fruit growers of south-east Queensland are having to put up with the onslaught of the fruit-piercing moth yet again. Sands is advising them every step of the way.

More about moth control

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