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RESEARCH BRIEF

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Bogong moths and Parliament House

The Bogong moth (*Agrotis infusa*) migrates annually to the highest peaks in the Southern Alps where millions spend the hot summer months aestivating[1] in deep, dark crevices in rock caves among granite boulders. Parliament House, built on Capital Hill with its elevated floodlit flagpole and extensive lighting, disrupts the flight of the moths and acts as a giant light trap for moths migrating through the Canberra area during October and November. The moths treat the building as a temporary camp and it is often necessary to reduce the building's lighting to allow the moths to continue their migration south.

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Executive summary

The Bogong moth (*Agrotis infusa*) is one of the few species of moth or butterfly which migrates annually to a specific destination and then returns to the original breeding area six months later. It starts and finishes its life cycle on the slopes and plains west of the Great Dividing Range, generally in NSW. The adults migrate to the Southern Alps (Snowy Mountains) where they spend the hot summer. The Bogong moths use migration as a means of avoiding the harsh environmental conditions of their breeding areas thus enabling them to maintain relatively high populations.

The moths migrate to the highest peaks in the Southern Alps where millions spend the hot summer months aestivating in deep, dark crevices in rock caves among granite boulders. Predators of the adult moths in and around the caves include bats, pygmy possums, foxes, Australian ravens and currawongs.

It is not known exactly how Bogong moths navigate on their journey to and from the mountains. It is the light of the horizon that appears to play a part in maintaining flight elevation during their night flights, rather than the stars or the moon. Artificial light may distort the moth's view of the horizon, making it fly in a circular pattern around the light. Canberra is on the flight path of the Bogong moths, and Parliament House built on Capital Hill with its floodlit flagpole and extensive lighting acts like a giant light-trap for the moths migrating through the Canberra area during October and November.

The infrastructure managers of Parliament House have been wrestling with the Bogong moth problem since the building opened in 1988. The immediate response in 1988 was to trial turning off the lights. This appeared to be successful, enabling most of the moths to escape the confines of Parliament House. The moths that didn't escape left after-effects that lasted for months. Dead moths continued to be discovered in offices all over Parliament House. These carcasses provided a food and breeding source for carpet beetles and clothes moths.

Bogong moths have been found to transport arsenic from the grazing and cropping areas in the inland plains of eastern Australia to their resting sites in the mountains. Higher levels of arsenic were found in the soil and grasses in the outwash areas of some of the caves where the moths aestivate over summer, than in the soils and grasses in adjacent areas without moths.

Introduction

This paper updates a Parliamentary Library Background Paper, titled *Bogong Moths and the New Parliament House*, issued on 8 November 1988. The information in that paper came primarily from the studies on the Bogong moth by Dr I.F Common[2].

Community interest in the annual Bogong moth migration has been heightened in recent years with a moth concentration during October 2005 in Newcastle and other coastal areas,

and of earlier memorable events such as the evening track and field program and the closing ceremony of the Sydney 2000 Olympics. Such coastal concentrations of Bogong moths occur when north-west winds blow them towards the sea from their normal migratory course along the Great Dividing Range to the Snowy Mountains[3].

Canberra lies on the migration route of Bogong moths from the slopes and plains of south eastern Queensland and northern New South Wales to the highest mountains of the ACT and Kosciuszko National Park. Parliament House receives annual influxes of migratory moths in spring. Since it was opened in 1988, Parliament House has acted as a beacon which attracts varying numbers of these migrating moths from year to year.

This paper looks at the biology of the moth, its migratory habits, the problems experienced at Parliament House when moth numbers build up and the impact of control measures adopted to date. The paper also discuses evidence that the migrating moths transport arsenical compounds from the slopes and plains to their aestivation sites in the mountains.

The Bogong Moth, *Agrotis infusa*, a migratory species of moth

The Bogong moth, *Agrotis infusa*, is a migratory species of moth found in southern Australia. There are six or more species of the genus *Agrotis* in Australia and others are found elsewhere in the world. Only some of these species are migratory. *A. infusa* is a common species and is found in New South Wales, Victoria, Queensland, South Australia and Western Australia. However, it is not clear whether Western Australian populations are migratory. The Bogong moth is one of the few species of moth or butterfly which migrates to a specific destination and then returns to that same destination in subsequent seasons.

Life cycle of the Bogong moth

Breeding

The Bogong moth starts and finishes its life cycle on the slopes and plains west of the Great Dividing Range, principally in NSW. The adults migrate to the highest mountains of south eastern Australia where they spend the hot summer. Figure 1 shows the areas where larvae of the moth have been recorded. This includes some coastal areas. A small proportion of the Bogong moth population, however, does not migrate but instead remains on the slopes and plains west of the Great Dividing Range. These individuals tend to be smaller and have white hind wings.

In April and May, adult moths lay eggs in the fields of the western slopes and plains of New South Wales, Victoria and southern Queensland. These eggs hatch into caterpillars commonly referred to as cutworms because, rather than biting out sections of leaf, they fell seedlings and herbaceous stems by cutting through them and feed just under the soil surface on the felled plants[4]. These caterpillars are pale with brown head capsules, but turn green after starting to feed and may then turn brown if numerous.

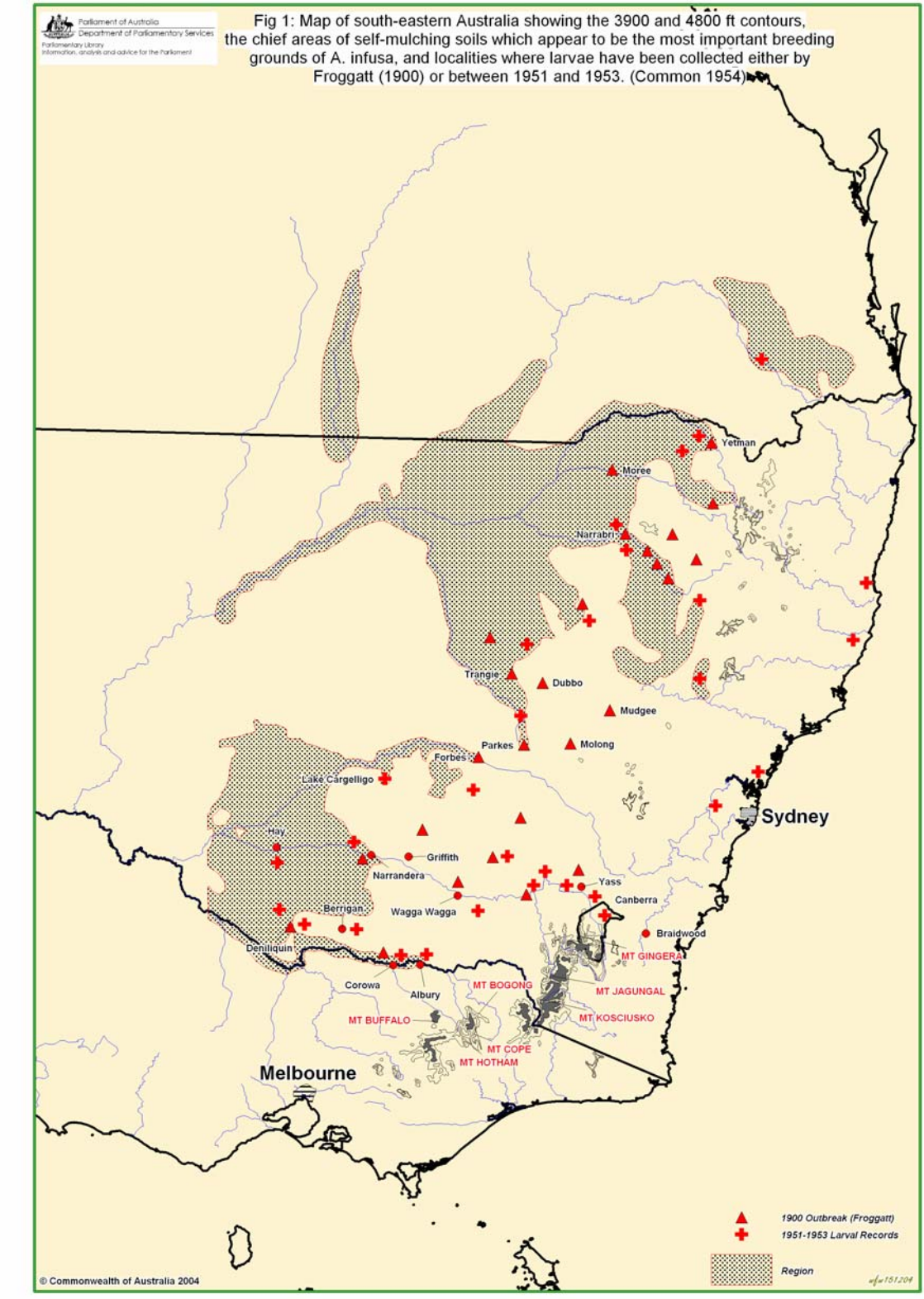
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Fig 1: Map of south-eastern Australia showing the 3900 and 4800 ft contours, the chief areas of self-mulching soils which appear to be the most important breeding grounds of A. infusa, and localities where larvae have been collected either by Froggatt (1900) or between 1951 and 1953. (Common 1954)
Yetman
Moree
Narrabri
Trangie
Dubbo
Mudgee
Parkes
Molong
Forbes
Lake Cargelligo
Sydney
Hay
Griffith
Narrandera
Yass
Canberra
Berrigan
Wagga Wagga
Braidwood
Deniliquin
MT GINGERA
Corowa
Albury
MT BOGONG
MT JAGUNGAL
MT BUFFALO
MT KOSCIUSKO
MT COPE
MT HOTHAM
Melbourne
1900 Outbreak (Froggatt)
1951-1953 Larval Records
Region
© Commonwealth of Australia 2004

The caterpillars feed at night, mainly on broad-leafed weeds and pasture plants. They do not appear to feed on grasses except where other foliage is unavailable. However, they have been known to damage young wheat. Outbreaks of the caterpillars may occasionally cause some minor crop or pasture damage. The caterpillars grow and moult[5] five times over the winter period. Their development is relatively slow due to the low temperatures in winter. The caterpillars pupate in late September or October, and after a short period emerge as adults. The adults feed on nectar from flowers and are active at night.

Some of the adults, which have emerged and started feeding, develop sexual organs, mate and lay eggs. This segment of the population stays in the breeding area to continue its life cycle. If there is sufficient food available there may be three generations of moths completed over the hotter months from October until April. Since the Bogong moth larvae feed on broad leaf plants, the food supply reduces with the onset of hotter weather when grass growth begins to dominate the pastures. Therefore, only a small proportion of the winter moth population can be supported in these areas over summer.

Migration

The bulk of the Bogong moth population does not develop sexual organs but instead departs the pastures and migrates in mass night flights.

It is not known exactly how they navigate on their journey to and from the mountains. However, light sources appear to play a part in maintaining flight elevation[6]. Moths migrate and fly actively under cloudy conditions and during a new moon. It is unlikely that the old theory, that moths are attracted to artificial light because they mistake it for a natural light like the moon or stars, is correct[7].

While moths may not be navigating by the moon or stars, it is yet to be demonstrated what other factors are important. Moths orient and maintain elevation at night by light, but it is probably by the light at the horizon and not by the stars or the moon since, given their ability to see polarised light, they probably can make out the horizon in cloudy conditions. This mechanism may allow them to maintain level flight over long distances. It is likely that the disruption of this orientation for flight that causes artificial lights to attract moths[8]. An artificial point source of light may distort the moth's view of the horizon, making it fly in a circular pattern around the light.

Unlike insects such as bush flies and other moths which are simply dispersed by the winds, the Bogong moths fly strongly towards the Southern Alps around October. Strong winds can blow them off course as happened in October 1988, during the September 2000 Olympics and in October 2005 when large numbers were blown into Sydney**.** They have even been found in New Zealand, having been blown across the Tasman Sea by strong westerly winds. However, since moths fly at low altitudes and at night when the winds are generally light, and rest during the day, significant numbers will remain on course and reach their correct destination.

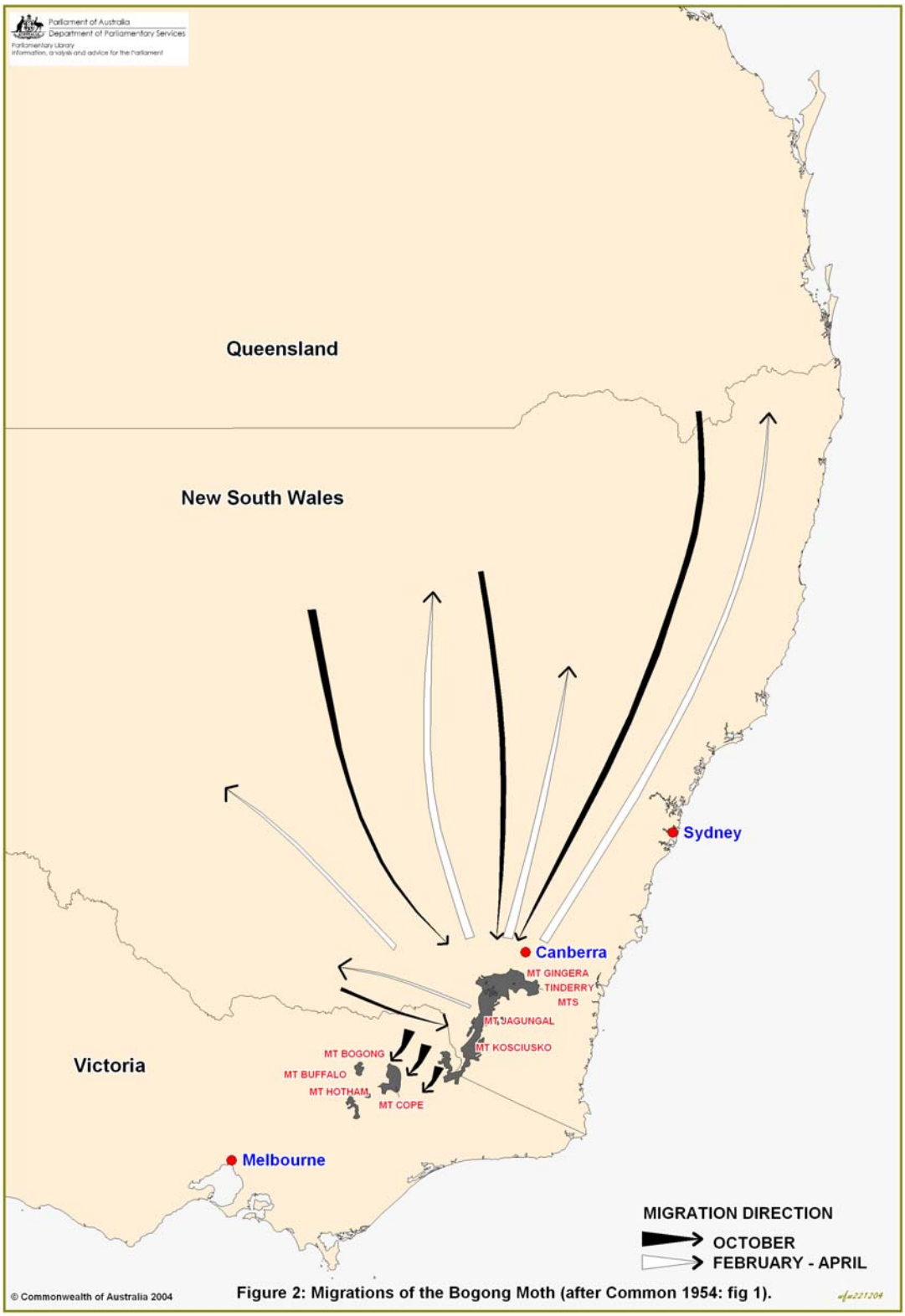

Figure 2: Migrations of the Bogong Moth (after Common 1954: fig 1).

Bogong moths require large amounts of energy to make their migration flights and to survive over summer. Much of the moths' energy comes from large fat reserves stored in their abdomens (up to 60 per cent of dry body weight). Much of this fat is laid down during food intake by the larvae, but the adult moths can also feed on nectar. The fat reserves are sufficient to carry the moths through their migration without feeding and it appears that some moths may indeed not feed during this time. Since nectar feeding can start reproductive development in some moths it is probable there is some genetically determined characteristic which prevents such sexual development until after the migrating moths start returning from the mountains to their place of origin in autumn. Some individuals do become sexually mature, mate and lay eggs en route.

Camping (Aestivation)

The moths migrate to the highest peaks in the Southern Alps where they spend the hot summer months. The moths arrive at these areas and seek out deep, dark crevices in rock caves among granite boulders, in the extensive Kosciuszko Batholith for example, where the temperature and humidity are fairly constant. Here the moths congregate in their millions and aestivate[9] (remain dormant) over three or four months of summer. They group together in the rock piles in large aggregations. This behaviour may be a mechanism to reduce moisture loss. The suitable sites where the moths aggregate are revisited year after year and are referred to as permanent camps. Some moths do not remain motionless all summer but become active for a brief period after dusk, before settling for the night in the camps.

Predators and Parasites

Predators of the adult moths in and around the caves include bats, pygmy possums, foxes, Australian ravens and currawongs. There is also a parasitic nematode (worm) which attacks adult moths in the caves.

The aestivating moths have some protection against the hunting bats. Moths have tympani (or ear drums) on their thorax (middle segment) which enables them to hear the echo location emissions from bats that prey on them when they venture into the open for brief evening flights from their summer camps. When they hear sharp sounds made by the bats in flight they are alerted to take evasive action.

In the past, aborigines of the hinterland areas travelled to the high mountains to exploit Bogong moths as a food source in late spring or early summer. They collected aggregating moths from the caves and rock shelters in the mountains. The moths were either singed in a fire to remove wings and scales and eaten immediately or ground into a paste and cooked into cakes which could be transported back to their camps.[10]

Return Journey

From February through to April, moths leave the caves and start to return to the western slopes and plains (see figure 2). This migration is not as dense as the spring event because the

moths don't leave en masse and because their numbers have been considerably reduced through the losses on the trip to the summer quarters and the predation and parasitism at their resting places. The mountains of the ACT become staging posts in autumn for migrating moths moving from mountains further south. From here, they travel in a span of directions between west and north-north east. The adult moths don't necessarily return to exactly the same place from where they emerged, but fly back to areas suitable for egg laying.

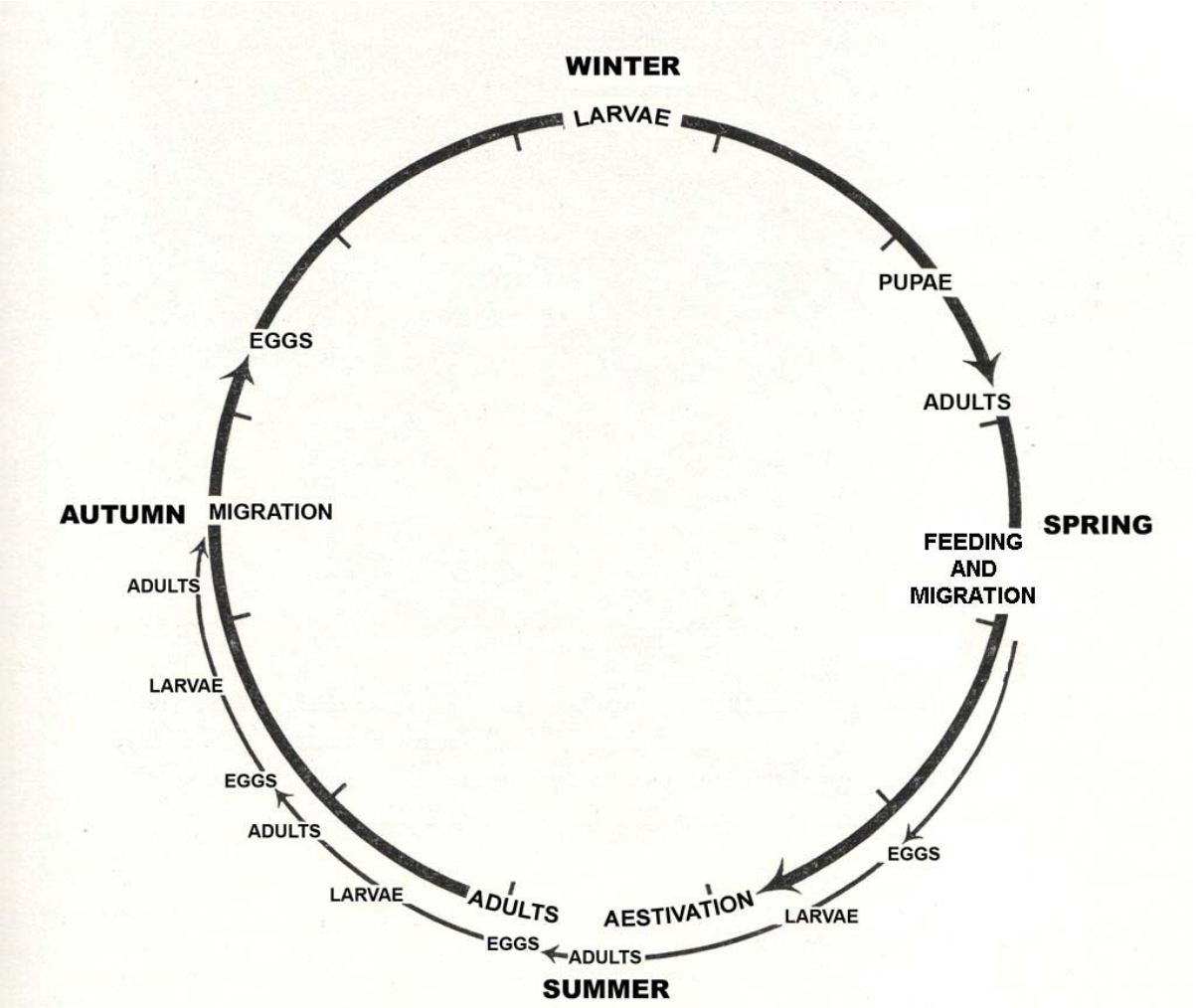

Figure 3. – Probable life cycle of the Bogong moth (after Common 1954:fig.12).

They travel at night and rest during the day. They feed on nectar and it is this diet, after the moths' summer aestivation period, that starts the development of their reproductive systems. The moths mate and eggs are laid in the slopes and plains of New South Wales and the Darling Downs of Queensland. The timing of the maturation of the eggs and hatching of larvae to coincide with the autumn emergence of broad-leafed pasture plants. This is the start of the next generation (see figure 3).

Survival Mechanism

The Bogong moth uses migration as a strategy of avoiding unfavourable environmental conditions in order to maintain relatively high populations. Other moths may pupate underground in the soil as a means of avoiding high summer temperatures.

As noted above, the numbers of Bogong moths that stay on the slopes and plains are far fewer than the migrating population. The sparse summer pastures can support far smaller populations of Bogong moth larvae than the winter pastures. In summer, grasses which are not palatable to moth larvae, dominate, whereas broad-leaf pasture plants take over in winter. In favourable habitats with adequate food, three to four generations of Bogong moths are possible annually but for the great majority of Bogong moths, the migratory population represents the one and only generation each year.

Parliament House as a moth trap

Canberra is on the flight path of the Bogong moths travelling to the high peaks of the Brindabella Mountains, such as Mt Gingera, and further south. Parliament House, built on Capital Hill with its elevated floodlit flagpole and extensive lighting, appears to disrupt the flight of moths migrating through the Canberra area. It acts like a giant light trap. Starting in early October, the Bogong months start congregating around Parliament House, treating it as temporary camp on their way to the mountains. When the powerful lights are illuminated continuously during the night, the moths are not able to fly away. Over the weeks, the warmer weather brings larger numbers of Bogong moths through Canberra, joining those attracted earlier. The moths attracted to Parliament House may mass in the nooks and overhangs of windows and courtyards to avoid the light and heat of the day in somewhat the same manner that they naturally aggregate in rock shelters of the mountains.

In October each year the sun, heat and noise of Parliament House keep the moths agitated and moving around the building. The moths that come into Parliament House enter through open doors. These moths cannot find their way out and die.

In 1988, moths entered the air conditioning ducts via the mesh covering the air intakes because the mesh size of the screen was too coarse. This problem was later remedied by changing to a smaller size mesh on the air intakes of the air conditioning systems.

The question has been asked whether the moths on the outside of the building eventually leave or stay for the summer, deciding that Parliament House is as good a camp as the granite tors in the Brindabellas and the Snowy Mountains? While it appears that some moths have settled in to the building for good, CSIRO scientists have suggested that they are merely making a temporary camp. It is the lights being left on all night that is preventing the moths leaving. If the lights were to be extinguished over several nights most of the moths would continue their migration[11]. The CSIRO scientists believe that the moths would move on even without the lights being turned off, but that this would take more time[12].

Managing the moth invasions since 1988

The infrastructure managers of Parliament House have been wrestling with the Bogong moth problem since the building opened in 1988. The immediate response in 1988 was to trial turning off the lights. Turning off the lights on the nights of November 3 and 4 1988 appeared to be successful. It enabled most of the moths to escape the confines of Parliament House. This was possibly assisted by the warm night temperature and a weather change that had passed through Canberra in the late afternoon, during the trial period.

The after-effects of dead moths were noticeable, however, for months following their first arrival in 1988. Dead moths continued to be discovered in offices all over Parliament House. Their carcases amounted to a food and breeding source for carpet beetles and clothes moths. A clothes moth infestation occurred as a result of them breeding in the carcasses of Bogong moth, resulting in significant damage to fabric in the House of Representatives[13]. In response, the then Joint House Department commenced spraying appropriate areas of Parliament House with an insecticide. The residual synthetic pyrethroid insecticide deltamethrin, known by the brand name Cislin 10, was used to discourage the moths from clustering in the crevices of the Parliament House building.

Some changes to minimise the attractiveness of Parliament House to Bogong moths included placing mesh over the air conditioning inlets to physically prevent entry and turning off lights in the windows of Parliament House after 11 PM. Initially the equipment necessary to turn off the window pelmet lights had not been installed. The then President of the Senate, in an answer to a question, said that connection of lighting relays had commenced in the week of 20 December 1988 to enable the window pelmet lighting and external lighting to be turned off during daylight hours [sic][14].

In Senate Estimates of 3 October 1989 the then Joint House Department outlined its program to reduce the attractiveness of new Parliament House to Bogongs:

> We have a program in place to try to alleviate the attraction of this building to the Bogong moth, which is currently flying over Canberra. The program mainly involves control of the external lights to the building, which are the ones which we believe are attracting the moth- the flagpole light, the curved wall lighting and the lighting on the sloping walls in the forecourt. We are turning those off certainly from midnight to dawn and we also have a program to lessen the impact of the internal lights. We are turning off the pelmet lighting, which can be done by the building monitoring system under block control, and we are asking cleaners and attendants to close all the blinds so that where people are working at night with the lights on it is not as bright from the outside. [15]

However these steps may not have been implemented routinely during the next spring since the Bogong moths returned to Parliament House in numbers in 1990. On 16 October 1990 the then Acting Speaker made the statement:

> For the information of honourable members, I have received questions from members concerning Bogong moths. I advise that the Joint House Department has undertaken the

> following action in an effort to control the presence of Bogong moths in the building and to reduce the attraction of the building itself to moths: Firstly, pelmet lighting in offices in both the Senate and the House of Representatives will be turned off as from this evening. Secondly, two of the four flagpole lights have been turned off. Thirdly, attendants have been asked to turn off all unnecessary office and suite lighting. Fourthly, a great number of external lights have been turned off, including ramp lights, lighting around the tennis courts, and in the formal gardens. Courtyard lighting will also be reduced.
>
> The engineering services section has discussed with the Australian Capital Territory authorities, road safety authorities and the Parliament House security controller the feasibility of turning off all or some of the street lights located on Parliament Drive. A fine mesh has been installed over external air intake and exhaust vents, and windows have been sealed to deny moths entry.
>
> Finally, an information circular is being issued today requesting occupants of the building to turn off lights in their offices and suites as they leave and not to leave doors to courtyard areas open during the day and evening as this has been a major avenue for entry for the Bogong moths. Housekeeping and cleaning staff maintain a continual program of cleaning out rooms, suites, corridors, et cetera, which have been infested with the moths. I assure the House that every action is being taken to contain Bogong moth infestations.[16]

The unintended side effect of these measures was a saving in electricity use. On the 4 December 1990 the President of the Senate made the statement

> On 16 October 1990, Senator Coulter asked me, in relation to the recent Bogong moth infestation, that a measure of the savings in electricity as a consequence of turning off the lights be made and that that be reported back to the Senate. The Joint House Department has advised me that the reduced lighting levels have saved an estimated $365 a week or $19,000 per annum in energy costs. Since moving to the new Parliament House, the Joint House Department has achieved a 10 per cent saving in energy costs. A comprehensive energy audit is presently being undertaken. Its recommendations will lead to further savings in energy costs. Senator Coulter's request to reduce the use of lights is being taken into account by the energy auditors.[17]

Bogong moths have continued to appear annually in varying numbers in Parliament House during October and November. The fluctuations in numbers are due to a variety of factors including:

- the impact of winds on the flight path;
- the numbers of larvae emerging and growing to adulthood in the slopes and plains of New South Wales; and
- size of the light sources in the ACT region that may attract moths and cause them to divert from their flight path.

The 1988 background paper made the following comment.

> It should be remembered that New Parliament House will remain a wonderful beacon to attract the spring migrations of Bogong moths for the next 200 years.

Insecticide bioaccumulation in Bogong moths

A paper published in 2001, indicated that the Bogong moths transported arsenic from the grazing and cropping areas of the inland plains of eastern Australia, where the larvae are found, to the aestivation sites in the mountains.[18] Higher levels of arsenic were found in the soil and grasses in the outwash areas of those caves where the moths aestivate over summer, than in the soils and grasses in adjacent areas without moths. The higher levels of arsenic in the outwash areas resulted in the death of the grasses. The elevated arsenic levels were also noted in the faeces of mammals that predate on the moths. Mountain pygmy possums, an endangered species found in the snow fields of the Kosciuszko National Park, had higher levels of arsenic as well, indicating that the moths may be the source of the arsenic in this area. The paper identified the probable source of the arsenic to be from the past use of arsenic by agriculture, in pesticides and in cattle and sheep dips in the breeding areas. An arsenic based insecticide is still licensed for use as a herbicide in New South Wales, in the form of monosodium methylarsonate (MSMA). Currently, MSMA is used as a post-emergent herbicide for cotton, where the moth larvae attacks emergent seedlings. It is unclear whether such herbicides may be the source of the high levels of arsenic in the moths from the South Ramshead caves or whether earlier uses of arsenical compounds have caused arsenic to accumulate in the soil. The study noted that Ramshead cave soils in the mountains above Thredbo had far higher arsenic levels than those moth sites in Mt Gingera in the ACT or Mt Buller and Mt Buffalo in Victoria. These site specific variations in arsenic levels would be consistent with Bogong moths in different aestivation sites coming from different areas. This hypothesis has yet to be resolved by genetic studies.

In October 2003, 14 dead currawongs (birds similar in size to magpies) were found in Parliament House gardens. Concerns were raised at the time that the cause of death could be related to high levels of arsenic in Bogong moths. Concerns were also raised at the time that the birds died by eating Bogong moths killed by the residual insecticide, Cislin 10 which had been sprayed to control ants, spiders and moths. Several bird carcasses were sent for autopsy but the results were inconclusive.

There is no specific evidence to support either theory as the possible cause of the currawong deaths.[19]

It was stated in the Department of Parliamentary Services 2003–04 Annual Report that Cislin 10 had been used for several years without bird deaths being recorded and that it was used to discourage the moths. The Estimates Committee was told that spider control, not moth control, was the prime purpose for using Cislin 10[20]. There was confusion whether the Cislin 10 was used to kill the Bogong moths or to stop them dying in Parliament House and forming a food source for clothes moths.

Estimates Committee Hansard of 3 November 2003 quoted Mr Bolton of the then Joint House Department (JHD) saying that it sprayed once a year in early spring, not particularly for Bogong moths, but that the spray had had an effect on them.

> It is a regime that is used—and it is used in a lot of Canberra—in the early spring to control spiders and a lot of other things, but it also does allow us to do some control on the moths. It is very important that it is only one aspect of moth control. Over the years all the air conditioning vents that come into the building have had a lot of stainless steel fine mesh put in place. As the President has advised Senator Lees in writing, to control the moths we presently use cleaners for about a month. I think it is six cleaners who work eight hours a day for virtually three to four weeks, trying to vacuum up these moths over this period of time, depending on how big the incursion is in the air. We also have at different times changed the lighting on the building to try and restrict the number of moths that come here. It is more difficult when the house is sitting, obviously, to do that than it is when the house is not sitting. You can turn off a whole lot more lights when it is not. So there is a whole series of things, and spraying is just one element.[21]

Mr Bolton said that if the then JHD did not deal with the Bogong moths in some way then they would have further pest control problems such as carpet beetle outbreaks which use the moth carcasses to live and breed in. He stated that Cislin 10 had a low toxicity for mammals and he did not believe that it posed any hazard to humans when sprayed as per the manufacturers instructions at the very dilute rate used to control insects. He said that Cislin 10 sprayed on porous surfaces of Parliament House would have a residual half life of about 20 days.

As a result of the death of the currawongs the Senate passed a motion moved by the then Senator Meg Lees:

> That the Senate—
>
> (a) notes:
>
> (i) the death of at least 14 currawongs around Parliament House during the last 2 weeks of October 2003, and the subsequent absence of most magpies and currawongs
>
> (ii) that the likely cause of the bird deaths is their consumption of contaminated Bogong moths
>
> (iii) that the contamination of the Bogong moths is most likely due to the application of Cislin, a pyrethrum-based spray, around Parliament House, to kill Bogong moths, and
>
> (iv) that the data sheet prepared by the manufacturers of Cislin notes that it is highly toxic to fish, aquatic organisms and bees and also toxic for birds in various concentrations, and

(b) asks that the Joint House Department cease any further spraying of Cislin, or other substances toxic to birds, in any concentration, in 2003 or in future years.[22]

Current Measures

On 7 October 2005, Hilary Penfold QC, the Secretary of the Department of Parliamentary Services issued an Information circular outlining measures to be taken in response to the Bogong moth migration.

2. During the next two months we can expect many Bogong moths to divert from their migration path and find their way to Parliament House. It is suspected that they are attracted by bright lights. External lighting levels around the building have been reduced to about half of normal capacity so that fewer moths are attracted to the building.

3. The moths usually congregate in caves over summer, and therefore seek out cool places around the building where they can mimic this behaviour. Many moths eventually find their way into the building through open doors and through various building crevices.

4. In the past an application of insecticide, Cislin 10, was used to control the moth. However, we have not used insecticides for moth control since September 2003. This means that building occupants have a bigger role to play in controlling the moths.

5. You can help by:

   (a) turning off the lights in your rooms when you leave (this also helps save energy and reduces greenhouse gas emissions)

   (b) closing the doors that open to courtyards

   (c) advising the Building Management Help Desk (extn 5045) if you notice where Bogong moths are gaining entry to the building.[23]

Summary

The almost two decades of history of Bogong moth invasion of Parliament House, a natural phenomenon, suggests that low cost, non-intrusive measures to prevent the problem will not be successful. Mitigatory action (closing doors, turning off lights and vacuuming up the dead moths) appears to be the appropriate response.

In 2005 Bogong moths started arriving at Parliament House in numbers at the end of September and had mostly departed by the middle of October, after supplying the local magpies and currawongs, and their young, with a substantial food supply.

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