The Transoceanic Migration of Lepidoptera to New Zealand — A History and a Hypothesis on Colonisation

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Abstract

This paper surveys the known historical records of foreign butterflies and moths in New Zealand appearing in the literature between 1855 and 1967. Then detailed observations made between 1968 and 1976 are discussed, with particular reference to the fact that many of these migrant species have been able to breed in New Zealand for varying periods of time. Finally the flights across the Tasman Sea are discussed, with reference to both the prevailing weather patterns at the time and to the significance of these migrant insects in the colonisation of New Zealand.

RECORDS FROM THE LITERATURE

The Rev. Richard Taylor (1855), writing in his book "Te Ika a Maui", recorded amongst the butterflies and moths of New Zealand the red and yellow admirals (*Bassaris gonerilla* (F.); *B. itea* (F.)), the Australian painted lady (*Cynthia kershawi* McCoy), the blue moon (*Hypolimas bolina nerina* (F.)), 2 hawk moths, and a moth known to the Maoris as Pari kori taua, and which is now known as the moon moth (*Dasypodia selenophora* Guenée). All these species, with the exception of the N.Z. red admiral, are known from Australia, and would be considered as migratory insects.

Fereday (1874) listed Lepidoptera recorded in New Zeaand prior to 1871. All the species named by Taylor (1855) were included, as well as many other species known to occur in Australia such as *Agrotis munda* (Walker), *Helicoverpa armigera conferta* (Walker), *Cosmodes elegans* (Donovan), *Spoladea recurvalis* (F.), and *Diasemia grammalis* Doubleday.

In the same paper Fereday discussed 2 isolated records of the monarch butterfly, *Danaus plexippus* (L.), a species which was new to New Zealand. He discounted the possibility of it having been introduced deliberately because there was no record of such an introduction, but had much to say on the subject of accidental introduction: "The 'blown-over' theory entertained by many entomologists with respect to the appearance in England of butterflies rarely seen there, but common on the continent of Europe, cannot be reasonably applied in this case. That a butterfly could be blown over such an expanse of ocean as it must travel over to reach New Zealand seems to me impossible. The tales of clouds of butterflies seen at sea, thousands of miles from land, are as unreliable as those of the sea serpent".

Later, Fereday (1877) described as new to science a moth found in Wellington in 1870, which he called *Catocala traversii*; this is a synonym of *Achaea janata* (F.) which occurs in Australia. He also recorded (Fereday 1877) a female blue moon from Napier, and as this species was at that time also known from Australia and Asia, he concluded that: "this strengthens the opinion expressed in my previous paper on the Monarch Butterfly as to New Zealand and Australia having been connected, or nearly connected with the continent of Asia".

Colenso (1879) reported finding and breeding larvae of the moon moth, an Australian species known since the early days of New Zealand's settlement.

G. V. Hudson (1887) reported collecting 7 specimens of the meadow argus, *Precis villida* (F.), on the beach at Paremata and at Wainuiomata, and seeing many others at Paekakariki. He concluded that: "there can be little doubt that this is a true native of New Zealand which has been previously overlooked, as it is quite impossible that so many specimens could have been accidentally introduced by artificial means". In fact it is not a native species. In the same paper he reported catching the crimson speckled footman, *Utetheisa pulchelloides vaga* (Jordon), at Wainuiomata, the first specimen taken in New Zealand of this widespread species, and also stated that the Australian painted lady was also more abundant that year than he had seen it before. Meyrick (1880) discussing Hudson's observations and records of the first specimens of the crimson speckled footman said: "Probably an occasional immigrant – although a feeble-looking insect it possesses extraordinary capabilities of flight and is sometimes met with far out at sea". This is the first hint or suggestion I can find in the literature that some insects might migrate to New Zealand by their own powers of flight.

Buller (1905) reported, in March, that Mr C. O'Connor had captured 2 specimens of the silver-striped hawk moth, *Hippotion celerio* (L.), and seen a dozen or more at Titahi Bay, and that G. V. Hudson had caught one at Nelson, and stated: "noting the fact that it has appeared in two places on the West Coast, it is not unlikely to be an Australian species brought over to New Zealand by westerly winds, in view of the fact that the hawk-moth family are possessed of sustained powers of flight". Buller also noted that at the same time Mr O'Connor had found the convolvulus hawk moth, *Agrius convolvuli* (L.), a moth normally confined to the Auckland district, to be common in Wellington, and O'Connor had also recorded *Achaea janata* frequently in the same month at Titahi Bay. Mr O'Connor had also recorded the crimson speckled footman at Titahi Bay that summer, only the second occasion it had been found in New Zealand. Howes (1906) also recorded *Achaea janata* in March 1904, this time from Motueka, and Hudson (1908) reported the capture of the lesser wanderer, *Danaus chrysippus petilia* Stoll, in 1904 in Thames, the first record of this species in New Zealand. Obviously many unusual, exotic, and eye-catching insects appeared throughout the country in March 1904.

Hudson (1908) noted records of the blue moon in Wellington, and the orange-sucking moth, *Othreis materna* (L.), in Dunedin in March 1907. The orange-sucking moth had previously been recorded at Makara Beach in May 1906; it was concluded that it had arrived in a consignment of fruit.

Meyrick (1911) published a revision of the larger New Zealand moths, which included the first record in New Zealand of *Argyrogramma albostriata* (Bremer & Grey) (as *Plusia oxygramma* Hübn.), and referred to many species mentioned above as immigrants, and one must assume therefore that it was appreciated at that time that some Australian species arrived in New Zealand "under their own steam".

At the end of October and early November 1938, Sorenson (1939) recorded over 30 specimens of the moon moth from throughout Southland, in the Milford area, and even from Stewart Island. He was puzzled, because in New Zealand they were usually found after Christmas, and their food plants (*Acacia* species) were absent from the Milford area. He queried the origin of all these large Australian moths, and wondered whether they had hibernated, been introduced as eggs on imported hardwood poles, or whether they had flown to New Zealand, as the Milford area was the closest land to Tasmania and southeast Australia.

The next published record is that of Wise (1958), who reported the lesser monarch breeding here.

Ramsay and Ordish (1966) published details of a large immigration of the blue moon to New Zealand some years earlier, in 1956, and mentioned that the immigration coincided with west to northwest winds.

Holloway (1962) published records of the Australian evening brown butterfly, *Melanitis leda bankia* (F.), from Taranaki, as well as blue moons and the lesser monarch, after prolonged westerly winds, and intimated that their probable point of origin was northeastern Australia.

RECENT EVIDENCE FOR TRANS-TASMAN MIGRATION

The present study, which spans the years 1968 to 1976, started when several Australian species were recorded simultaneously in Taranaki after prolonged northwesterly winds.

The chronological records presented above bring out the following important points:

1. Conspicuous Australian insects, such as colourful butterflies and moths, have been recorded in New Zealand fairly regularly since the early European settlement of the country.
2. When one exotic species is discovered other foreign butterflies and moths are often discovered at the same time.
3. Whilst sometimes records are of a single specimen, very often many insects of the same species are recorded at the same time.
4. Frequently the records of a given migrant species are from widely-separated localities at the same time, thus indicating a widespread invasion.
5. The species found are often migrant species in other parts of the world.
6. The more recent records have been observed after northwesterly winds.

Apart from visual recordings of butterflies and larger moths, the present records have been compiled from light trap records, mainly from Taranaki where I have been running a mercury vapour light trap in Manaia for the past 12 years. Manaia is a small South Taranaki town about 2 km from the sea. Local lists of Lepidoptera have been compiled during the earlier years of trapping, and detailed records of migrant species have been kept since 1968.

Other entomologists have sent records and specimens from time to time from other Taranaki coastal localities, Auckland, Nelson, Wellington, and North Auckland; all of these being localities close to the west coast. With the background list of species which appear year after year, it is relatively easy to pick out species that are not normally present.

Unless specimens are marked in Australia and recaptured here, a highly unlikely occurrence, it is of course impossible to state definitely that an unusual insect found in New Zealand, albeit a known Australian species, is in fact an immigrant specimen. Australian species have been known to breed in N.Z. from time to time, and some of them are established breeding species. This makes it very difficult to decide whether a given specimen of an Australian species has in fact just arrived in N.Z., or whether it is a specimen which has bred here.

With the paucity of lighthouses and shipping off our western coast, direct sightings of migrating insects are extremely sparse. However, Common (1958) recorded the greasy cutworm, *Agrotis ipsilon aneituma* (Walker), having been seen at the lights of a ship in early February 1957, and also flying around the ship by day, when the ship was 500 km from the west coast of N.Z. I have frequently seen the greasy cutworm flying in over the sea with the westerly

wind during February and March, both in Taranaki and on the west coast of the South Island, and at these times the moth is found frequently sheltering under driftwood on the beach, and is usually extremely common in coastal localities.

In the absence of direct sightings, one of the following facts may help one to decide whether the specimen in hand is an immigrant or not:
1. It is a species not normally found in the area and is known to be Australian.
2. It is an Australian species not normally found in the area at that particular time of the year.
3. It is taken after recent strong and prolonged northwest winds.
4. Smoke from Australian bushfires is present in N.Z. at the same time as the record.
5. It is a known migratory species.
6. The record is accompanied by simultaneous records of other migrant species.

It was because of the lack of direct sightings of migrating insects that I arranged in 1970, when the Sedco 3 oilrig was stationed some 40 km west of Taranaki, for any moths that flew onto the rig to be sent to me with a note of the wind conditions prevailing at the time. Most of the records (Fox 1970) were taken when the wind was in the westerly quarter and often in excess of 30 km/hour. This would make it very difficult for the specimens taken on these occasions to have flown from the Taranaki coast. Most of the records were of the greasy cutworm, and occurred from the middle of January through to the middle of April, a time when this species was extremely abundant in Taranaki. Dissection of the abdomens of the specimens from the oilrig revealed immature ovaries, as are the ovaries of this species when migrating between Egypt and Europe, and the ovaries of aestivating colonies of the closely related Bogong moth, *Agrotis infusa* (Boisd.) in Australia. One specimen of a pyralid, *Herpetogramma licarsisalis* (Walker), a pasture pest on paspalum, and the first record of this moth in N.Z., was obtained when the wind was blowing from the west at 50 km/hour. Another species recorded from the oilrig was the cosmopolitan and world-wide migrant, the cosmopolitan armyworm, *Leucania separata* (Walker), renowned for its dramatic upsurges in numbers in N.Z. giving rise to severe pasture damage.

During the 8 seasons during which this survey has taken place there have been 6 migrant butterflies recorded, one of which, the longtailed blue, *Lampides boeticus* (L.), has now established as a resident breeding species in Nelson, Auckland, and New Plymouth. The Australian painted lady and blue moon have each appeared in varying numbers for 5 out of the 8 seasons. The Australian painted lady has been known to breed here in the summer months, producing offspring in mid-summer and again in the autumn. Table 1 summarises these records.

Table 1.—Migrant butterflies recorded in N.Z. 1968-1976. (+ = under 5 specimens; ++ = 5-15 specimens; +++ = over 15 specimens).

Species	Collecting season							
	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76
Danaus chrysippus petilia	2 larvae			2 larvae				
Cynthia kershawi	+++			+++	++	+++	+	
Hypolimas bolina nerina			+++	+++	3	2	2	
Lampides boeticus	++		+++	+++	+++	+++	+++	+++
Precis villida		1	1			+	2	
Melanitis leda bankia				1				

Amongst the moths 22 species have been recorded here as definite migrants and of these no fewer than 6 species, *Agrotis ipsilon aneituma, Agrotis infusa, Spodoptera litura* (F.), *Plusia argentifera* Walker, *Achaea janata,* and *Utetheisa pulchelloides vaga* have bred here and their larvae have been found. Another 5 species *Leucania loreyi* (Duponchel), *Argyrogramma albostriata, Helicoverpa punctigera* (Wallengren), *Radinogoes tenuis* Butler, and *Ectopatria aspera* (Walker) are presumed to have bred here as their populations increased over several seasons from the time of the original records (Table 2). With the exception of *Plusia argentifera, Agrotis infusa,* and *Radinogoes tenuis,* the remaining 8 species have probably established themselves in the warmer parts of the country.

Table 2.—Migrant moths known to have bred in N.Z. 1968-1976. (+ = under 5 specimens; ++ = 5-15 specimens; +++ = over 15 specimens).

Species	Collecting season							
	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76
Agrotis infusa	+++	++	+			+	+	
Agrotis ipsilon aneituma	+	+++	+	+++	+	+	+	+
Leucania loreyi						++	+++	++
Spodoptera litura		+	+	+	++	+++	+++	++
Argyrogramma albostriata		1	+	+	+	+	+++	+
Plusia argentifera	++			++		+++		
Helicoverpa punctigera	++			++	+++	+++	+	+
Achaea janata			++	++		1		
Ectopatria aspera	1		+	++				
Radinogoes tenuis						++	+++	
Utetheisa pulchelloides				+++		+++	++	

The other 11 species of migrant moths have been recorded on rare and infrequent occasions; sometimes just a single isolated specimen, on other occasions several individuals of one species, and occasionally large numbers of one species in a single invasion. Table 3 summarises the records for 8 seasons.

Table 3.—Migrant moths of rare occurrence found in N.Z. 1968-1976. (++ = 5-15 specimens; +++ = over 15 specimens).

Species	Collecting season							
	1968-69	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76
Spodoptera exempta		1			1			
Herpetogramma licarsisalis		1						
Anomis vitiensis (Butler)			1	1				
Hypocala australiae		1	3		1			
Loxostege affinitalis						++		
Tathorhynchus exsiccata						1		
Platysenta illecta						+++		
Cosmodes elegans						++	2	1
Othreis materna					1	++		
Hippotion celerio					1		1	
Utetheisa lotrix Cramer								1

Apart from these records there are another 8 species of Australian moths which have been known to be resident breeding species in New Zealand for a long time, and yet whose numbers seem to be increased markedly from time to time, often coinciding with the arrival of the other migrant species mentioned above.

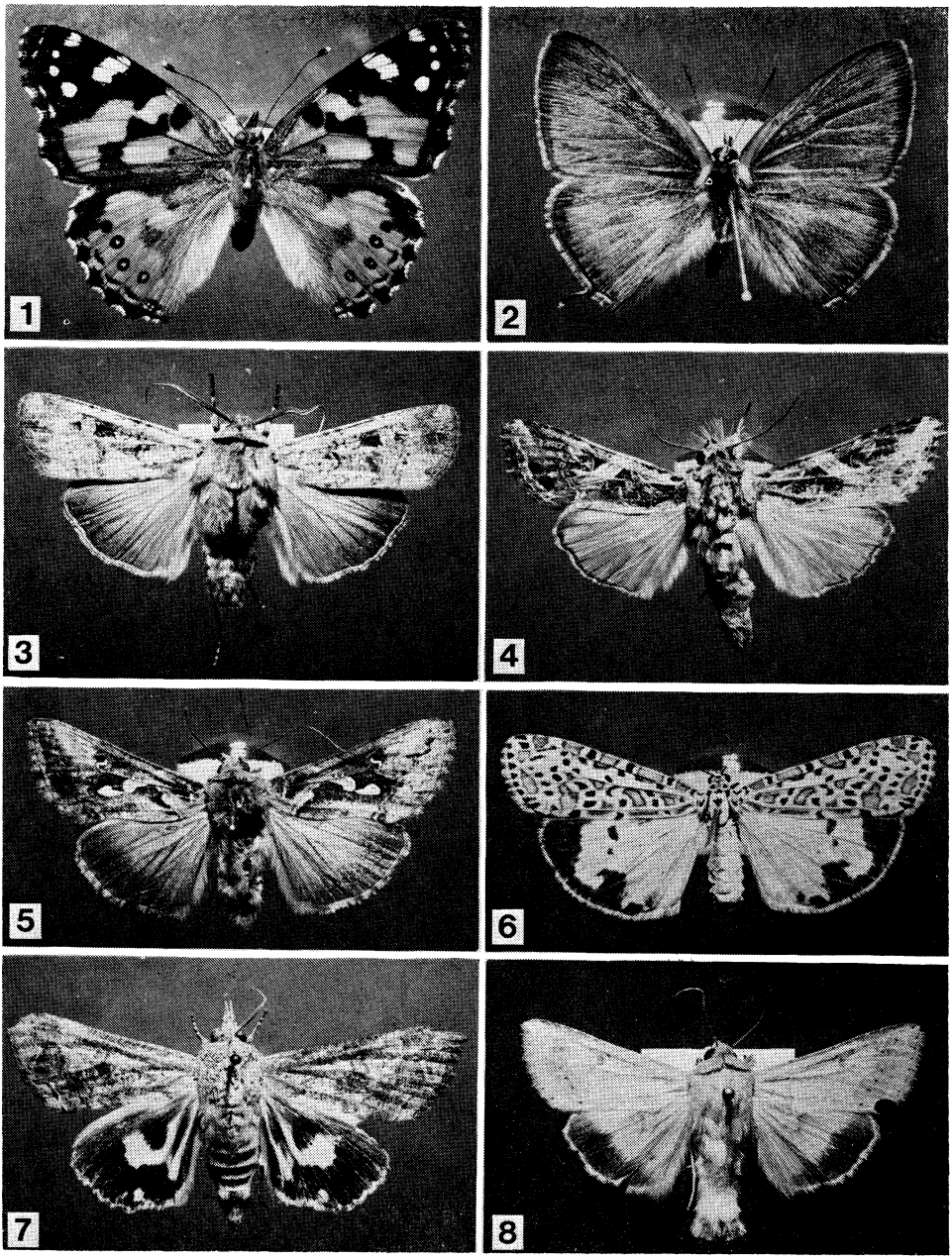

Plate 1. Eight lepidopteran species known to have migrated to New Zealand from Australia since 1968 (a.e. = alar expanse). 1 *Cynthia kershawi* (a.e. = 49 mm); 2 *Lampides boeticus* (a.e. = 27 mm); 3 *Agrotis infusa* (a.e. = 46 mm); 4 *Spodoptera litura* (a.e. = 36 mm); 5 *Plusia argentifera* (a.e. = 42 mm); 6 *Utetheisa pulchelloides vaga* (a.e. = 35 mm); 7 *Hypocala australiae* (a.e. = 56 mm); 8 *Helicoverpa punctigera* (a.e. = 38 mm).

These species are therefore presumed to be species which have migrated to New Zealand in the past, and where local populations are augmented by recurrent influxes of new arrivals. They are: *Dasypodia selenophora, Dasypodia cymatoides* Guenée, *Leucania separata, Agrotis munda, Salebria sublignalis* (Walker), *Spoladea recurvalis* (F.), *Schrankia costistrigalis* (auct.), and *Phrissogonus laticostatus* Walker.

This makes a total of 36 species of Lepidoptera which I consider have continued to migrate to New Zealand in the past 8 years. The vast majority occur after prolonged strong west to northwest winds, and these winds are obviously a major factor in their arrival here.

THE MODE OF TRANS-TASMAN MIGRATION

The weather map for 3 Oct 1971 (Fig. 1a) shows a deep depression to the south of New Zealand, with an associated band of strong west to northwest winds on its northern side blowing from southern Queensland and northern New South Wales onto the North Island. Next day, 4 Oct 1971 (Fig. 1b), the northwesterlies were still blowing, and a cold front was approaching Taranaki. It was after the passage of this cold front, with its accompanying belt of heavy rain and violent thunderstorms, that I obtained no fewer than 9 specimens of *Utetheisa pulchelloides vaga* in my light trap; 2 hours before the passage of the cold front not a single specimen of this migrant moth was collected. There were also records from Westport in the South Island on 4 Oct 1971, and from New Plymouth on 5 Oct 1971, giving a band of simultaneous records of at least 400 km, signifying a very large invasion. It has been noted time and time again that records of migrant Lepidoptera have been made after the passage of a cold front in a northwesterly airstream. As well as *Utetheisa pulchelloides vaga,* very many Australian painted ladies and the moth *Helicoverpa punctigera* were recorded in early October 1971.

It is not only the northwest winds associated with the northern edge of a depression coming on to New Zealand that bring the migrant insects, for they can arrive with any prolonged westerly airstream irrespective of its meteorological derivation. The weather map for 23 Apr 1972 (Fig. 1c) shows a moderately strong northwesterly airstream between a depression to the southwest of the country, and a high pressure area to the northeast of New Zealand. It has with it two associated cold fronts. Immediately after this, *Utetheisa pulchelloides vaga* and blue moons were found commonly in Taranaki.

Several Australian painted ladies, 2 species of tropical armyworms (*Spodoptera litura* (F.) and *S. exempta* (L.)), a peacock moth (*Dasypodia cymatoides* Guenée), *Argyrogramma albostriata,* and very many specimens of *Spoladea recurvalis* were caught after the westerly winds in association with a low pressure area to the south of the country on 15 Mar 1976 (Fig. 1d) (Fox 1973). The above examples of the weather conditions and simultaneous migrant records show that when conditions are favourable there is a large influx of Australian Lepidoptera into New Zealand, not only in numbers of individuals, but also in numbers of species.

According to Tomlinson (1973) conditions suitable for the transport of insects across the Tasman occur on average 21 times annually. Theoretically, therefore, if weather patterns have remained fairly constant, New Zealand could have been aerially bombarded with Australian insects 21 000 times in the last 1 000 years, and, if thinking in geological terms, 21 000 000 times in the past 1 000 000 years. Opportunities, therefore, for the introduction and possible establishment of Australian species here in New Zealand have, to put it very conservatively, been fairly frequent!

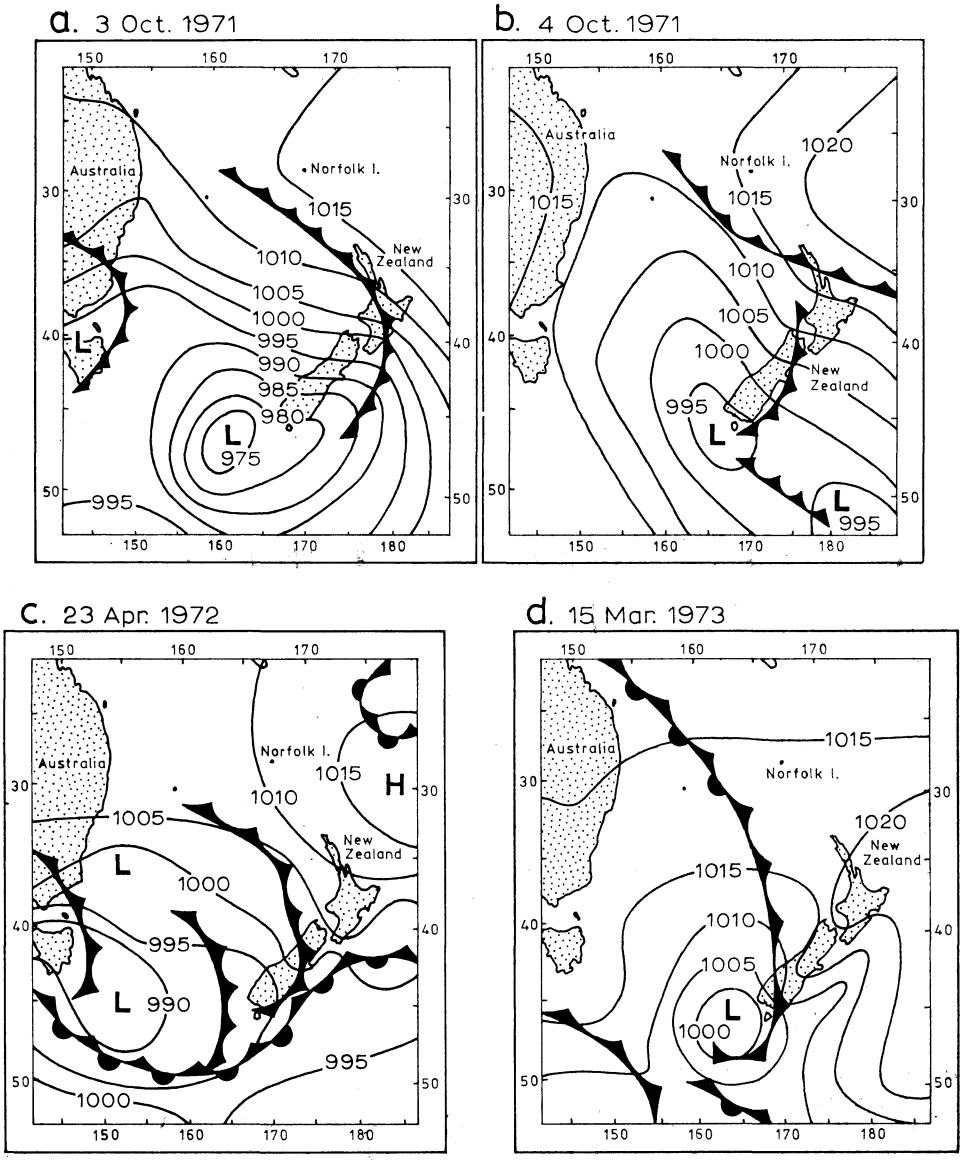

Fig. 1 a-d N.Z. weather maps. a, 3 October 1971; b, 4 October 1971; c, 23 April 1972; d, 15 March 1973.

The strong and prolonged westerly winds and often associated cold fronts are commonplace weather patterns in New Zealand. The more uncommon tropical cyclones, which arrive here occasionally in the summer months, also bring with them their share of Australian Lepidoptera. On 4 Feb 1971, Cyclone Rosie was stationary off the coast of New Plymouth. The next day 3 specimens of a large tropical moth, *Hypocala australiae* Butler, which had been seen only once before in New Zealand, were found in a light trap in New Plymouth (Fox 1971). Of even more interest was the tail end of Cyclone Pam which passed over Jackson Bay in South Westland on the night of 9 Feb 1974 with very strong winds for six hours. The next day was fine and still, and there

flying on the beach in South Westland were hundreds of Australian painted ladies, 2 lesser monarchs, and a blue moon all in exceptionally good condition. Soon after this several records of the orange-sucking moth were obtained from throughout Otago.

Another factor influencing the arrival of insects in New Zealand from Australia are the presence of large bushfires in Australia, when presumably many insects get swept up in the strong updraughts of hot air, and then caught up in the prevailing westerly winds. Smoke from Australian bushfires and immigrant insects are often recorded simultaneously (Fox 1969).

Tomlinson (1973) has described several ways how insects could become uplifted in masses of rising air over Australia, and the meteorological conditions necessary for their transport and eventual descent in New Zealand. This implies that they are carried passively in fast-moving air masses, often at high altitudes. That some low level dispersal of Lepidoptera also takes place is evident from the records from the oil-rig, the occasional ship, those seen flying in over the sea, and also records from Norfolk Island coinciding with records of the same migrant species in New Zealand (Holloway 1977 and pers. comm.).

The time for such a journey is surprisingly short. A very large immigration of Australian insects occurred in October 1973 after 2-3 days of northwesterly gales. In this invasion 4 well known migrants occurred commonly and, in addition, 4 species were recorded that had never been seen in New Zealand before: the 3 noctuids *Platysenta illecta* (Walker), *Radinogoes tenuis*, and *Tathorhynchus exsiccata* (Led.) and 1 pyralid, *Loxostege affinitalis* (Fox 1975). Back trajectories drawn by the meteorological office show that the likely origin of the Taranaki specimens was somewhere between Newcastle and Brisbane on the Australian coast some 55-60 hours previously. When vagrant species were recorded after a prolonged storm from the northwest on 27 Jan 1975, back trajectories on this occasion gave a probable origin in southern Queensland some 48 hours beforehand (Fig. 2); this gives an average travel speed of 48 km/hour.

Whether or not this flight over the Tasman is a purely passive phenomenon, the insects merely being carried along in a fast-moving airstream, or whether they contribute in some way themselves to their air speed, is a matter for conjecture. The very large migratory flight to New Zealand in October 1973 followed "An extremely favourable season for plant growth in Australia, when many of the opportunist species reached very high adult populations and extensive flights occurred" (Dr I. F. B. Common pers. comm.). In fact all of the 8 species recorded in this 1973 invasion were known migratory species. The vast majority of the Australian insects recorded as vagrants or migrants in New Zealand are known migratory species. The other species observed may well be migratory also, as there have been very few observations of lesser-known moths in the Southern Hemisphere. On very many occasions we can get confirmatory evidence from Australia that show records in New Zealand occur a few days after there has been a known migration in Australia, and, if not a migration, there are often indications that the species has been particularly common in Australia during that season.

It is quite amazing how records of species which are found frequently here in New Zealand are usually made at exactly the same time each year within a day or two. The Australian painted lady is always first observed in October, usually towards the middle, and the blue moon is very constant in its occurrence, being nearly always recorded at the end of April and early May. Likewise the Bogong moth is usually recorded towards the end of October and early November, and these records coincide with its migratory flights within Australia

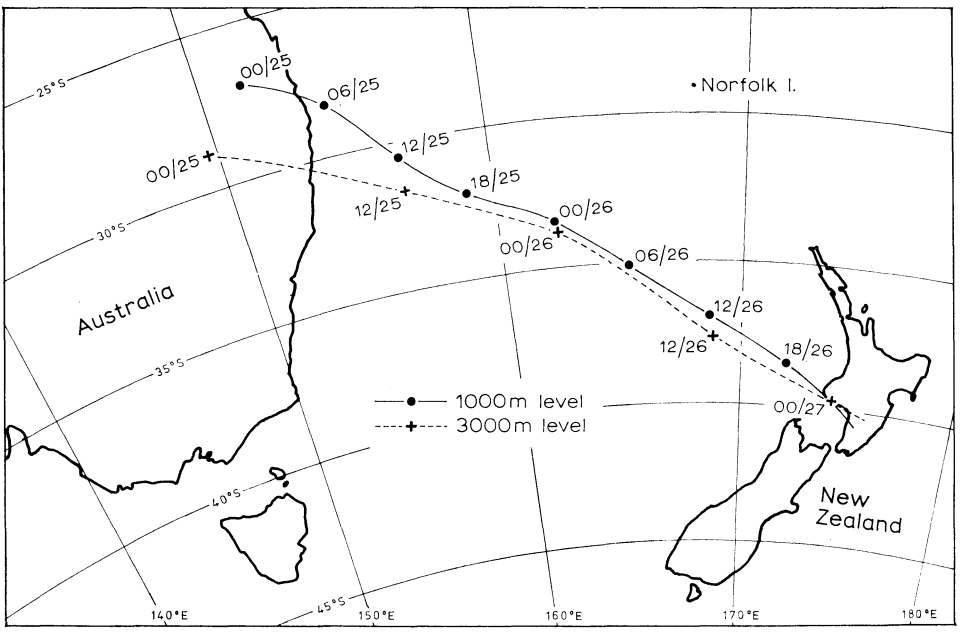

Fig. 2 Calculated back trajectories from Manaia 0000 GMT 27 January 1975, to show the likely source of specimens collected. The numerals on the trajectories refer to hour and day, e.g., 18/25 means 1800 GMT on 25 January.

up to the mountains of southeast Australia where it aestivates. It would appear that on some occasions the migrating flights of the Bogong moth get blown off course by the prevailing westerly wind and are blown very many miles out to sea, and occasionally reach New Zealand.

All these records from within Australia would tend to confirm the impression that the butterflies and moths arriving in New Zealand are probably upon a migratory flight within Australia and are somehow blown off course, or get caught up by various meteorological conditions, and thereafter get transported to New Zealand. Whilst the flight across the Tasman might therefore be a purely passive flight, being carried along with the wind, the flight within Australia is not.

I feel therefore that it is justified to call these insects migrants, and to refer to the sudden influxes of these species into New Zealand as migrations. If the whole process was merely a passive process we would expect to find records of non-migratory species, but in fact we have not done so.

THE COLONISATION OF NEW ZEALAND

As mentioned above, there have been numerous opportunities for arrival of Australian Lepidoptera in New Zealand over the years. The fate of these insects when they reach New Zealand is varied. Their chances of producing offspring depends on the suitability of the climate and the availability of their foodplants. It therefore follows that genera which are polyphagous, such as *Agrotis, Helicoverpa,* and *Prodenia,* have a far greater chance of survival than those which are host-specific. Naturally if the host plant does not occur in New Zealand they have no chance of survival, and this would apply above all to species which are restricted to tropical foodplants, e.g., *Hypocala australiae.*

Some tropical species, however, such as *Achaea janata,* have become temporarily established from Auckland northwards where the host plant *Ricinus communis* (castor oil plant) abounds.

It has often been said that many of these tropical species cannot colonise New Zealand because our climate is too cold, but I have seen several species in Queensland flying in the warm sun in mid-winter after quite severe frosts. These have included the blue moon and the lesser monarch, both species which have been reported breeding in New Zealand, but yet have never become established. It could well be that such species as these can withstand very cold conditions (up to −5°C), provided they can be heated by the sun during the day, and this would not happen very often with our cloudy and wet winter climate.

However, many species have found our climate suitable, and host plants available, and have established, e.g., the yellow admiral and monarch butterflies, the convolvulus hawk moth, the golden Y moth (*Chrysodeixis eriosoma* (Doubleday)), and the greasy cutworm, to mention but a few. It would, I feel, be feasible to postulate that all our non-endemic Lepidoptera that have not been deliberately introduced, such as the cinnabar moth, *Tyria jacobaeae* (L.), for the control of ragwort, or accidentally introduced, such as the small white butterfly, *Pieris rapae* (L.), in crates of cabbages, have in fact arrived in New Zealand in a wind-borne fashion across the Tasman from Australia. Some successful colonists have presumably only been able to survive here since the introduction of their food plants by man for horticultural purposes, e.g., *Dasypodia* species feeding on acacias and *Albizzia* species, the monarch butterfly on swanplants (Asclepidaceae), and even the longtailed blue on gorse and sweetpeas. The gum emperor moth, *Antheraea eucalypti* Scott, which is thought to have been introduced accidentally as ova or young larvae on imported gum seedlings, is not considered to be a migrant species.

Climatic factors are obviously important, for some species seem to be found only in the warmer areas of the country despite an abundance of their foodplant throughout New Zealand, e.g., *Leucania loreyi,* a grass feeder, is only found north of a line drawn from Taranaki to Hawkes Bay, and, likewise, *Spodoptera litura* has recently colonised the same area; both species become more common as one moves northwards. *Ectopatria aspera* is present in North Auckland, Three Kings Islands, and in the Nelson district.

Some migrant species are found breeding in the summer months, and yet do not seem to survive the winter, e.g., *Cynthia kershawi* and *Agrotis infusa,* whereas others seem to breed for a year or two and then disappear despite an abundance of host plant, e.g., *Utetheisia pulchelloides vaga, Cosmodes elegans, Radinogoes tenuis,* and *Plusia argentifera* (which on occasions has been reported as a pest on tobacco in Nelson).

CONCLUSIONS

Opportunities for the colonisation of New Zealand and other areas of the Southern Pacific by winged insects, in an easterly direction, across wide expanses of ocean are abundant. That this method of colonisation over a long period of time is most successful is borne out by the fact that very many of the migrant species mentioned above, and including the yellow admiral, have also been found on the tiny, remote Pacific island of Rapa some 3 000 km NE of New Zealand (Gates Clark 1971). The actual process of colonisation is a very dynamic affair and is in a constant state of flux. Different species are at different stages of colonisation, varying from those that are completely successful and resident

New Zealand breeding species, to those that struggle to produce one generation. Some successful species appear to have their numbers augmented by immigrants from season to season. Others breed for a few years and then die out, only to be re-introduced at a later date by yet another invasion. Some immigrant records are of such small numbers as to be insignificant in terms of introducing the species here under present climatic conditions. Unfortunately for New Zealand agriculture the most successful colonists are invariably serious pest species because of their polyphagous habits.

I have been unable to find papers with equivalent documentation of long distance dispersal for so many species, such as presented here. In only the past 8 seasons, there have been positive records of 36 migrant species that have travelled and survived journeys of over 2 000 km across the ocean, and about half of these have still been able to breed when they have arrived here. This transoceanic passage of insects must, therefore, be a very important factor in the colonisation of islands in the Pacific.

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Review — Lepidoptera of Norfolk Island

HOLLOWAY, J. D. 1977: The Lepidoptera of Norfolk Island, their biogeography and ecology. (*Series Entomologica Vol. 13*). Dr W. Junk b.v., The Hague. vi + 291 pp, 140 figs, 29 plates, 7 tables. ISBN 90 6193 124X.

Norfolk Island is a speck in the Tasman Sea 676 km from New Caledonia, 772 km from New Zealand, and 1368 km from Australia. The biota show most affinities with Australia and eastern "Malesia" (Malaysia, Indonesia, Papua-New Guinea, etc.), and fewer with New Zealand and New Caledonia.

Jeremy Holloway's first book (Holloway 1976) authoritatively dealt with Borneo "Macrolepidoptera". This, his second, authoritatively describes and usefully depicts the "Macrolepidoptera" (Noctuoidea, Sphingoidea, Geometroidea) of Norfolk Island. Thus this book, along with G. S. Robinson's (1975) "Macrolepidoptera of Fiji and Rotuma" form a useful, "interlocking" compendium of near-Pacific "Macrolepidoptera", shortly to be joined by Dr Holloway's book on New Caledonian Lepidoptera. At last, those of us interested in moths of the near-Pacific are catered for handsomely. There is an appendix at the end giving a brief resumé of other lepidopterous groups and the other insect orders.

The species descriptions (no keys) include synonymies, full references, diagnostic characters, biological information where known, distribution, a photograph of the adult, and in many instances genitalia drawings.

But there is more. The book provides admirable chapters on climate, on geology and soils, on the effects of human occupation on the environment, and on phytogeography. These chapters provide the setting for an understanding of the Norfolk I. macrolepidopterous fauna.

The sampling programme and methodology is outlined, and after the taxonomic section comes 120 extremely useful and lucid pages dealing with: vagrancy of moth species to Norfolk I., the methods of numerical analysis of faunal samples, sources of and evolution within, the Norfolk I. fauna, local distribution patterns, seasonal and other population fluctuations, and a concise discussion on diversity and the equilibrium theory of island biotas. In these chapters, Dr Holloway expands some of the approaches he and Jardine described earlier (Holloway & Jardine 1968).

For lepidopterists the book is both useful, and in the later chapters, extremely instructive. The last chapter, "Moths as Biotic Indicators", points out some of the values (and restrictions) of systematic light trapping.

For general biologists, chapters VI-XI give a clear useful exposition of the theories, statistical treatments, and sampling techniques necessary in modern biogeography. Because of this, the book should have a wide readership.

Finally, it is pleasing to note that one of our members, Dr K. J. Fox, has contributed in no small way to Dr Holloway's information.

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