Conservation status of two rare New Zealand geometrid moths

Frontispiece. An adult male of each of the two threatened moth species. Top: *Asaphodes stinaria* (colour slide L15 084, type specimen from the New Zealand Arthropod Collection, *reproduced by permission of Landcare Research).* Below: *Xanthorhoe bulbulata (Photo: B.H. Patrick)*. Both have a 24 mm wingspan.

Conservation status of two rare New Zealand geometrid moths

SCIENCE FOR CONSERVATION 145

Brian Patrick

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

Science for Conservation presents the results of investigations by DOC staff, and by contracted science providers outside the Department of Conservation. Publications in this series are internally and externally peer reviewed.
Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

ISSN 1173–2946
ISBN 0–478–21946–6

Cataloguing-in-Publication data
Patrick, B. H. (Brian H.)
Conservation status of two rare New Zealand geometrid moths / Brian Patrick. Wellington, N.Z. : Dept. of Conservation, 2000.
1 v. ; 30 cm. (Science for conservation, 1173-2946 ; 145)
Includes bibliographical references.
ISBN 0478219466
1. Moths—New Zealand. 2.Asaphodes stinaria. 3. Xanthorhoe bulbulata. 4. Rare insects—New Zealand. I. Title. Series: Science for conservation (Wellington, N.Z.) ; 145.

CONTENTS

Conservation status of two rare New Zealand geometrid moths

Brian Patrick

Otago Museum, PO Box 6202, Dunedin, New Zealand

A B S T R A C T

Two formerly common and widespread conspicuous New Zealand geometrids, *Asaphodes stinaria* and *Xanthorhoe bulbulata*, have suffered a severe decline in both distribution and population numbers over the past 60 years. Data from specimens in eight collections are used to show the timing for this contraction and decline. A research project initiated in 1995 to search for surviving populations and elucidate the biology and reasons for the decline has had very limited results. Ten populations of *Asaphodes stinaria* have been found and the first larvae and eggs obtained. No individuals or populations of *Xanthorhoe bulbulata* have been located since two individuals were found in 1979 and 1991. A compilation of the host-plants of congeneric species is presented that includes many previously unpublished records. Recommendations on future research are presented. The current conservation priority status, Category A, of both species is supported.

Keywords: Geometridae, Larentiinae, *Asaphodes stinaria, Xanthorhoe bulbulata*, historical records, threatened status, conservation status, recommendations, biogeography, biology, foodplants, *Ischnocarpus*, *Paranotoreas fulva*, New Zealand

Patrick, B.H. 2000. Conservation status of two rare New Zealand geometrid moths. *Science for conservation 145*. 21 p.

1. Introduction

Two species of New Zealand geometrid, *Asaphodes stinaria* (Guenee 1868) and *Xanthorhoe bulbulata* (Guenee 1868) (Lepidoptera: Geometridae: Larentiinae) have suffered a significant decline in both geographical extent and population numbers over the past 60 years (Patrick 1989, 1994a, b; Peat & Patrick 1995).

Both species are highly distinctive as adults, as they are about 24 mm in wingspan and brightly coloured (Figure 1). Both are now threatened with extinction and given the highest priority for conservation action, Category A (Molloy & Davis 1994; Patrick & Dugdale 2000). Sherley (1989) and New (1990) have highlighted the need for research on the reasons for this decline. Both species are listed by the Otago Conservancy of the Department of Conservation as in need of conservation action in their Conservation Management Strategy (Department of Conservation 1999, p. 133).

Both species were described from single specimens captured by Christchurch lawyer R.W. Fereday and sent to Achille Guenee in Paris for formal description (Dugdale 1988). He published these descriptions in a paper that appeared in the *Entomologists' Monthly Magazine* (Guenee 1868). The stated original localities for them, which are the type localities, are 'Canterbury' for *A. stinaria* and 'Christchurch' for *X. bulbulata*. Hudson (1898, 1928) illustrated both of these colourful species in his monographs on New Zealand Lepidoptera and listed early records.

Taxonomically, both species are distinct within their respective genera and are not considered to represent species complexes.

As is often the case with larentiines, the species are attracted to light as well as being easily disturbed by day. *X. bulbulata* has been found to be active by day in open grassy areas, while *A. stinaria* appears to be mainly nocturnal, with only a few records of it being diurnal.

1.1 RECORDS OF *Asaphodes stinaria*

Hudson (1898), citing Meyrick (1884), stated of *Asaphodes stinaria,* 'it seems to be fairly common, frequenting *Carex subdola*'. Philpott (1904) found *A. stinaria* to be very common at the Matukituki River near Wanaka (Otago), and also stated (Philpott 1917) that it 'frequents rough herbage in the vicinity of forests' at Invercargill, Dunedin, Queenstown and Lake Wanaka, November and December. Hudson (1928, 1939) records it from Waiouru (central North I.) and Puketiritiri (Hawkes Bay) in the North Island, and Mount Grey, Christchurch, Mt Hutt, Waiho Gorge, Otira, Dunedin, Queenstown, Lake Wanaka, Niagara, Clinton River, Mackinnon Pass (both Fiordland) and Otatara near Invercargill. He stated that it 'frequents tussock country or grassy openings in scrubby forest' between November and February. Hudson (1939) cited Clarke's two records (Clarke 1933) of the species in Fiordland. Prout (1939) illustrated the species but added no further information in relation to its distribution or ecology. The next record of the species was that of Howes (1946), who captured

single specimens at both The Wilderness and Gorge Hill, east of Te Anau on 11 December 1944. These are areas of bog pine and mixed shrubland/ copper snowgrass/herbfield. Dugdale's capture of one male on 7 December 1963 in the Rongahere Gorge at the base of the Blue Mountains and five males at Franz Josef were the next captures of the species. Meanwhile Davies (1973, 1986) recorded a single *A. stinaria* at 960 m in beech forest on the Kaweka Range, Hawkes Bay on 3 January 1964. In correspondence to me before he died, he stated that this was the only specimen of the species he ever saw.

Since then the species has been found at just ten sites in Central Otago, western Otago, and Westland regions between Wakatipu and Haast. In all, 31 individuals have been seen. Sites include the eastern entrance to Kawarau Gorge (Patrick 1994a), Five Mile Creek, Bobs Cove, The Gorge and Fernhill (all in Queenstown area), Devils Staircase (Lake Wakatipu area), Kidds Bush (Lake Hawea), junction of Muir Creek and Haast River, and Teapot Flat (Jackson River) (Brian Lyford pers. comm.). John and Geraldine Ward collected five males at a 6-watt ultraviolet light-trap on the access road to Franz Josef Glacier on 9 December 1999.

All of these adults have been found within the period 1 December to 5 January, between 1986–2000. Most have been attracted to ultraviolet light at night, but two individuals have been found by day. One was disturbed by day at the Devils Staircase on the eastern margin of Lake Wakatipu, the other spotted flying at 9 am on the morning of 28 December 1998 following a night when nine individuals came to the ultraviolet light (Brian Lyford pers. comm.).

In total, 127 specimens have been located in collections (Table 1) representing seven conservancies of the Department of Conservation (Southland, Otago, West Coast, Canterbury, Wellington, Hawkes Bay, and Tongariro/Taupo), highlighting how common the species once was. Table 2 lists the seven institutions and private collections that hold specimens of *A. stinaria*, together with the number of specimens from each locality. Interestingly, there are no specimens or records of the species from Nelson or Marlborough—both areas of high biodiversity with a significant number of endemic taxa. Where dates of capture are available they show clearly that there is only one generation per year, with 74% of adults emerging in December, 13% in January, 7% in November and 4% in each of February and March. The emergence pattern of specimens collected in

TABLE 1. NUMBERS OF SPECIMENS IN COLLECTIONS.

	Asaphodes stinaria	*Xanthorhoe bulbulata*
Auckland Museum	7	11
Canterbury Museum	32	30
British Museum	20	37
Museum of NZ	21	19
Otago Museum	9	3
NZ Arthropod Coll.		
Landcare Research	13	10
B.Lyford Queenstown	25	0
Totals	127	110

TABLE 2. *Asaphodes stinaria* LOCALITIES AND COLLECTIONS.

LOCALITIES	COLLECTIONS						
	BRITISH MUSEUM	NZ ARTHROPOD COLLECTN.	AUCKLAND MUSEUM	MUSEUM OF NEW ZEALAND	CANTER-BURY MUSEUM	OTAGO MUSEUM	BRIAN LYFORD
NEW ZEALAND							
no data	6				6	3	
HAWKES BAY							
Kaweka Range				1			
CENTRAL NORTH IS.							
Waiouru				1			
WELLINGTON							
Titahi Bay				2			
WEST COAST							
Otira				5			
Franz Josef		5				5	
Waihi Gorge				1	2		
Haast River							1
Jackson River							10
Maruia Springs					1		
CANTERBURY							
Mount Hutt	2						
Mount Grey					20		
'Canterbury' holotype	1						
New Brighton					1		
Drayton					2		
OTAGO							
Queenstown area	8			2			10
Devils Staircase							2
Bobs Cove							1
Kidds Bush							1
Ben Lomond	2	2	2				
Wanaka		1		1			
Beaumont		1					
Kawarau Gorge						1	
SOUTHLAND							
Invercargill	1	4		2			
Milford Track			5				
Gorge Hill				1			
The Wilderness				1			
Mossburn				1			
Niagara				1			
Eglinton Valley				2			

recent years have remained consistent with these data. Males are much more likely to be collected, with only 25% of adults collected being female.

1.2 RECORDS OF *Xanthorhoe bulbulata*

Hudson (1898, 1928, 1939) lists Awapiri, Kekerengu (both Marlborough), Christchurch, Castle Hill, Lake Pukaki, Ranfurly, Hyde, Waipori, Dunedin, Lake Wakatipu, Takitimu Mts, Oreti River, and Invercargill as localities for *Xanthorhoe bulbulata*. He stated that it 'frequents open, grassy places, from sea-level to elevations of from 2000–3000 feet' (660–930 m). Similarly, *X. bulbulata* was stated to be 'common' by both Philpott (1901), who found it at Mt Linton, western Southland, and Lewis (1901), who found it in the Mt Ida area in Central Otago. Lewis went on to say that, on the Maniototo Plain in Central Otago, '... and with them the common *X. bulbulata*, which keeps on in undiminished numbers until Christmas, and then takes a back seat, though never disappearing...'. Philpott (1904) found it in sandhills of the New River, Invercargill, and also records it (Philpott 1917) from 'rough herbage in open areas, on lower slopes only', August to March, from Takitimu Mts, Ben Lomond and Invercargill. Philpott (1907) and later (Philpott 1912) under the pseudonym of 'Student' describes the habits of *X. bulbulata* in the dune system at Riverton on the Southland coast. He comments on the 'contrast colouring' of fore and hind wings of the species and its survival value:

> Now and then a *Xanthorhoe bulbulata* takes wing. This moth is an excellent example of what is known as 'contrast colouring'. The upper-wings are dull grey and the under-wings bright orange-yellow. When on the wing the yellow of the under-wings is boldly displayed and the moth becomes a striking object, but if pursued it frequently drops among the herbage and closes its wings. This act at once transforms what appeared to be a brilliant insect into an inconspicuous grey one, and the ruse is almost always successful in avoiding capture.

Hudson (1928) records the species from Kekerengu (Marlborough), Christchurch, Castle Hill, and Dunedin, between September and March. Specimens in the Canterbury Museum collected by Stuart Lindsay between 1922 and 1934 come from a variety of localities in the Canterbury area including Hoon Hay, Governors Bay, Bottle Lake, and Mt Grey, while White found it on Mt Karetu and at Pukeatua between 1927 and 1933. At about the same time Clarke (1933) found the species to be 'common, in October, Oreti River and Takitimu Mts.' George Howes of Dunedin was the next to record the species. He took one specimen labelled Obelisk (presumably on the Old Man Range, Central Otago) on New Year's Day 1940. Prout (1939) illustrated the species but added no further information as regards distribution or abundance.

Since that date only two individuals have been found; one male flying by day inside a building in Queenstown 24 January 1979 and one female which died in an automatic light trap in the eastern entrance of the Kawarau Gorge between 20 February and 14 March 1991 (Patrick 1994a). An extensive sampling/trapping effort has failed to detect the species since, either by day or night.

TABLE 3. *Xanthorboe bulbulata* LOCALITIES AND COLLECTIONS.

	COLLECTIONS					
LOCALITIES	BRITISH MUSEUM	NZ ARTHROPOD COLLECTN.	AUCKLAND MUSEUM	MUSEUM OF NEW ZEALAND	CANTER-BURY MUSEUM	OTAGO MUSEUM
NEW ZEALAND						
no data	3		1		2	1
TARANAKI						
New Plymouth	1					
WELLINGTON						
Wellington	1					
HAWKES BAY						
no specific locality					1	
MARLBOROUGH						
Kekerengu				5		
Awapiri				1		
WEST COAST						
Greymouth	1					
CANTERBURY						
Christchurch	3				5	
Castle Hill	2				3	
Lake Pukaki				1		
Lake Tekapo					1	
Mount Grey		3			1	
Mount Hutt					3	
Fairlie	1					
Pukeatua					6	
Governors Bay					1	
Mount Karetu					3	
OTAGO						
no specific locality			3	1		
Ranfurly	10			2	3	
Nevis	6		1	1	1	
Ben Lomond	1	1				
Wedderburn		1	2			
Hyde				1		
Middlemarch	5		1			
Obelisk			3	1		
Kawarau Gorge						1
Queenstown	1					1
Cromwell	2					
Waipori				3		
Dunedin				2		
SOUTHLAND						
Invercargill area		3		1		
Greenhills		1				
Takitimu Mts		1				

Of the 110 specimens in collections (Table 1) by far the majority were collected up to 1940, but it is informative that only six individuals were collected between 1930 and 1940. These 110 specimens come from 8 conservancies of the Department of Conservation (Southland, Otago, West Coast, Canterbury, Marlborough, Wellington, Taranaki, and Hawkes Bay), highlighting the former wide distribution of the species. As with *A. stinaria* there are no records of the species from the Nelson region. Table 3 lists the six institutions that hold specimens *of X. bulbulata*, together with the number of specimens from each broad locality. Summarising these 30 broad localities, which are made up of 40 recorded locations, by date of collection, with number of localities in brackets, gives the following pattern of decline:

1860–1930s	Canterbury broadly including Banks Peninsula, inland valleys and lower slopes of ranges and Christchurch area (14)
1890–1920s	Mackenzie Country and inland South Canterbury (3)
1890–1910s	Coastal Marlborough (2)
1890	Wellington area (1)
1900–1930s	Coastal and inland Southland, including Takitimu Mts (4)
1900–1940s	Central Otago area including Strath Taieri (9)
1910s	Dunedin area including Waipori Gorge (3)
1910s	Coastal Taranaki area (1)
1910–1919	Western Otago area; Queenstown and Ben Lomond (2)
1979–1991	Western Otago–Central Otago (2)

Specimens from Greymouth, West Coast, and Hawkes Bay have no dates or other details that might assist deducing their date of capture.

The species has been found from near sea level to just above the tree line (930 m).

Males and females appear to have been collected in about equal numbers. The species has been collected from September till April (Philpott states August to March for Invercargill area), with peaks in November and March, and smaller peaks in the months between these latter two months. This may indicate two broods per season in some localities such as Invercargill, Dunedin and Strath Taieri, where records possibly spanning the full season exist.

2. Objective and procedures

2.1 OBJECTIVE

To understand the reasons for the decline of these two once common, endemic moth species and initiate management that will lead to their recovery.

2.2 PROCEDURES

Seven steps were taken to achieve this objective:

- Examine the literature pertaining to the two species together with data associated with specimens in the main collections, to build up a picture of geographic distribution and seasonal abundance.
- Collect live adult females at likely sites and attempt to obtain fertilised eggs.
- Look at closely related species in their genera to assist deduction of host plants.
- Rear larvae on a range of likely host plants.
- Once their hosts are deduced, site visits should reveal breeding sites and ecological information.
- Assess threats to host plants or ecosystem based on ecological information gleaned.
- Instigate recovery plan based on this information and recommend appropriate management including monitoring.

3. Results

3.1 *Asaphodes stinaria*

Ten populations of *A. stinaria* have been located within western Otago–West Coast amongst 338 possible sites sampled by day or night. The survey area included all regions of Otago, Southland, Canterbury and West Coast. Regular large collections of nocturnal moths have been received from colleagues and analysed from regions all over New Zealand, particularly Canterbury, Nelson, and Marlborough during the duration of the project. None of these contained this species.

The genus *Asaphodes* is endemic to New Zealand and contains in excess of 50 species (B.H. Patrick unpublished data; R.C. Craw pers. comm.). The genus is important from both a biodiversity and biogeographical standpoint in New Zealand as it is one of the most diverse genera of moths and is widely distributed with representatives in the Chatham, Stewart, and Sub-Antarctic Islands, and

with local endemics in most regions. Craw (1986) redefined the genus and illustrated the larval characteristics.

On 25 December 1992 three larvae of *A. stinaria* hatched from eggs laid on 12 December by a female collected at Fernhill, Queenstown by Brian Lyford. Unfortunately they died in the mail! They were pale yellow with neat rows of grey lines over their dorsal region but separated at regular intervals by an equal area of no such lines. While the larval food-plant of *A. stinaria* has not yet been confirmed, it is likely to be a dicotyledonous herb. It will possibly be a species of native daisy (Asteraceae), *Hydrocotyle* (Apiaceae), a native chickweed *Stellaria* (Caryophyllaceae), *Plantago* (Plantaginaceae), *Cardamine* (Brassicaceae) or *Ranunculus* (Ranunculaceae), judging by congeneric species that have been reared. In total I have reared fifteen other species of the genus of which *Asaphodes clarata, A. helias, A. recta, A. adonis* and *A. prasinias* were reared on species of *Ranunculus*. Additionally *A. oraria, A. frivola, A. omichlias, A. recta, A. cataphracta, A. oxyptera* and *A. aegrota* have been reared on introduced lawn daisy (*Bellis*), *A. frivola, A. oxyptera* and *A. abrogata* reared on *Plantago* species, *A. philpotti* on *Hydrocotyle* and *Cardamine* species, *A. helias* on forest herbs including *Cardamine* and *Ranunculus* species, and *A. cinnabari* reared on a herbaceous exotic daisy *Hypochaeris radicata.* The larvae of *A. beata* were found on, and apparently were feeding on, an assortment of forest floor herbs in the genera *Epilobium, Cardamine,* and *Stellaria* in the Dunedin area. In captivity the 1st instar larvae of *A. recta* feed on *Senecio*, *Bellis,* and *Ranunculus*, but as they grow larger, only on *Ranunculus*. Apart from *A. helias, A. philpotti, A. oraria, A. beata* and *A. aegrota,* all these records are possibly artificial as the species have been reared from eggs in the laboratory and not been found in the wild feeding on these hosts. What is clear is that larvae in this genus feed on forest floor, wetland, coastal and inter-tussock herbs. Whether these moths are monophagous or polyphagous requires more detailed research, including extensive field searching. It is worth noting the adaptation of several species to exotic herbs, with the larvae of *A. oraria* and *A. aegrota* found feeding on the common lawn daisy, *A. abrogata* on *Plantago coronopus,* and *A. helias* on an exotic buttercup.

3.2 *Xanthorhoe bulbulata*

Neither Brian Lyford of Queenstown nor myself have found adults of *X. bulbulata* in Otago, Southland, Canterbury and West Coast since the project began in 1995, despite repeated visits to and trapping in likely and historical areas. Collectively we have sampled 285 sites, either by day or night, over this area since the project began. Additionally, likely host-plants in the family Brassicaceae have been searched for larvae without success. Craw (1986) illustrates the larval characteristics. Large and regular collections of nocturnal moths have been received and analysed from a number of colleagues working in Canterbury, West Coast, Nelson, Marlborough, and the North Island. None of these collections contained this species.

In New Zealand the genus *Xanthorhoe* contains six named species (Craw 1986) where larval hosts are known feed exclusively on members of the plant family Brassicaceae. Of the three species reared, *X. frigida* feeds on *Cheesemania wallii* and probably other *Cheesemania* species (Patrick et al. 1992), *X. orophylla* on *Cardamine,* and *X. semifissata* on *Cardamine* and exotic Brassicaceae (both B.H. Patrick unpublished records). One potential host-plant from that family that has suffered a massive decline in both abundance and distribution is the tall herb *Ischnocarpus novae-zelandiae* (Dopson et al. 1999). Coincidentally, this plant has its last stronghold in the western Otago area where it survives on steep bluffs. But despite much searching, no larvae have been found on surviving colonies of this plant. Even if this plant was the larval host, or one of the larval hosts, then another explanation is needed for decline outside the known range of *Ischnocarpus. Ischnocarpus* records in collections extend from Marlborough to Otago, sea level to 1500 m, so records of *X. bulbulata* from Southland, West Coast and North Island may require an alternative explanation for their foodplant.

It is possible that the host of *X. bulbulata* is a herb of another plant family, but this possibility has not been investigated in the field. Skou (1986) in a review of the geometrids of northern Europe, lists ten species in the genus *Xanthorhoe*. Of these the host plants of nine are recorded, and only two are restricted to Brassicaceae. Another two are monophagous on *Plantago*, a widespread genus which contains both native and exotic species in New Zealand. The rest are polyphagous on herbs that include *Galium, Stellaria, Bellis, Senecio, Polygonum,* and *Geranium*. All of these latter genera are present in New Zealand and most contain native species. Examination of a thorough botanical description of a site where *X. bulbulata* was once found to be locally abundant—Otatara Dunes near Invercargill (Logan & Holloway 1934)—reveals several possible hosts including *Mentha cunninghamii, Plantago raoulii, Colobanthus muelleri, Hydrocotyle heteromeria, Gunnera* species, and *Geranium sessiliflorum*. The first named was stated to be common and, like *X. bulbulata* appears to have suffered a decline in such open sites, so may be a strong candidate for being the host of *X. bulbulata*.

4. Discussion

It is highly likely that the rapid decline documented for these two New Zealand geometrid moths is indicative of fundamental ecological changes wrought on the landscape by European settlers since the 1840s. It therefore follows that the identification of factors that have led to that decline and the successful conservation that may follow will have an important impact on habitat restoration in New Zealand.

New (1997) discussed the utility of certain moth species as 'umbrella species' for conservation because of their specialised feeding. He argued that by successfully conserving the target moth species and its food-plant, its community was also conserved. They are thus possible flagship or indicator

taxa. Further research will determine if these two geometrids fit this description.

Although extinction is a natural event, it is highly likely that for these two moths their comparatively rapid decline has been a consequence of human activities. Evidence for this is provided by the more rapid disappearance from the higher populated areas first (e.g. Christchurch). Because of the complexity of insect life cycles it is not easy to isolate the exact cause of such declines. It might not simply be the result of a decline in abundance of larval food plant or habitat destruction. Other factors such as disappearance of adult food sources, introduction of parasitoids, changes in habitat vegetation structure, and other disruptions to the life cycle could be to blame (Fry & Lonsdale 1991; Kirby 1992). These authors note that in Britain many moth species only declined once agricultural practices both intensified and used new technologies. The scale and rapidity of change has altered, and some native insects are unable to adapt.

While most lowland and montane moth species in New Zealand have suffered some decline, only a few have been brought to the edge of extinction. Patrick & Dugdale (2000) document 114 species or 6.8% of the New Zealand endemic Lepidoptera fauna that show a marked decrease in abundance and/or negative trend in overall distribution. Many of these are geometrids of the sub-family Larentiinae. This is probably because of their specialised food-plant preferences, especially their preference for herbs of damp areas. One of the most marked results of European settlement in New Zealand has been the drying out of various ecosystems because of wetland drainage, and also the burning of grasslands, road formation, closer settlement, and forest clearance. Favoured ecosystems of geometrids such as wet banks and herb-rich wetlands have become uncommon in settled areas.

Within their genera, *A. stinaria* and *X. bulbulata* are not the only rare species and other species including *A. obarata, A. imperfecta, A. ida*, *A. frivola,* and *X. frigida* are rarely collected. However, in contrast these appear to have always been uncommon or rarely collected species, the important difference being that the former two species were once common and widespread and have suffered a severe decline in both distribution and population numbers. All of these geometrids have been listed and discussed in terms of their conservation status by Patrick & Dugdale (2000)—both *A. stinaria* and *X. bulbulata* are listed in the highest category A. Given the many unanswered questions posed by this research, including the identity of the larval hosts, it is considered premature to put forward a management prescription at this stage.

Biogeographically the two species have similar distributions, both with many records across Southland, Otago, West Coast, and Canterbury and no records for either species on Stewart Island or the far north of the North Island. Records indicate that *A. stinaria* may have been absent from the north of the South Island and distributed within the North Island in the south, central, and east, while *X. bulbulata* was present in Marlborough in the northern South Island, and the south, east, and west of the North Island. Both species were found from coastal localities, through inland basins, to just above treeline in the regions in which they were recorded.

Ecologically it is clear that the two species had different habitat preferences, with *A. stinaria* an inhabitant of damp forest-edge communities, while *X. bulbulata* preferred dry open systems from the coastal to low alpine zone.

For *X. bulbulata* the future may be bleak, with adults unable to be located at former strongholds and its lowland and montane habitats continuing to be modified. The future looks much more promising for *A. stinaria,* with at least nine populations discovered from western Otago, south Westland, and Central Otago over the past 13 years. While it has disappeared from more modified eastern and southern localities, it has survived in the wetter west, where steep slopes and higher rainfall may have provided the species with refugia, temporary or otherwise.

We should not give up hope for *X. bulbulata* though, as another larentiine that was thought to be extinct was found to be locally common once its ecology/biology was properly understood in 1987. The diminutive *Paranotoreas fulva* had not been recorded for over 50 years until it was found to inhabit Central Otago saltpans where its larvae feed on the halophytic *Atriplex buchananii* (Patrick 1989). Earlier entomologists who had found it common in parts of Central Otago did not appreciate the species' habitat specialisation. Even though saltpan ecosystems have greatly decreased in size and abundance, this diurnal moth has since been found at over 33 sites in five low-altitude valley systems in Central Otago and the Mackenzie Country. In fact the species is so common at some sites that adults inhabit adjacent sites of open ground and feed on herbs such as *Stellaria gracilenta* (Patrick 1994a).

5. Conclusions

Department of Conservation field staff likely to encounter these two species should be given the relevant training so as to maximise the likelihood that—if they are in the right place at the right time—they have both the confidence and equipment to record/capture/observe either of these two species.

More detailed biological studies including population monitoring, are needed to determine the host plant, biology, host plant ecology, population trend, and threat to *A. stinaria* at known populations in western Otago and the West Coast (Otago and West Coast Conservancies).

Survey by light trapping should be carried out for *A. stinaria* from Canterbury northwards in forest-edge wetlands/damp herbfields. If a population of *X. bulbulata* is located, similar studies are needed. In particular, survey work should be undertaken in inland and coastal Marlborough for *X. bulbulata* adults, and further survey work for *X. bulbulata* in the Kawarau Gorge in Central Otago, particularly in areas of herbfield containing *Mentha cunninghamii*.

Further investigation of the host plant of *X. bulbulata* should also be carried out with possible hosts such as *M. cunninghamii*: that is, target areas of known extensive populations of this possible host.

Meanwhile, the current conservation status of Category A should be maintained for both species. Until more is known about the trend in population numbers for *A. stinaria* it would be prudent to maintain this highest status, despite the discovery of further populations.

6. Acknowledgements

I thank the Department of Conservation for funding this project (Investigation no. 1260), both while I was employed by the department and when I joined the Otago Museum. I am particularly grateful for the support given to me by Christopher Robertson, Department of Conservation, over the years in terms of operating and equipment funds. I thank Dr John Ward, Terry Hitchings, and Rod McFarlane of the Canterbury Museum for collections of nocturnal moths made in the course of their insect work. These helped considerably in endorsing the results of this work. I am grateful to my colleague Brian Lyford in Queenstown for his efforts in collecting in the Wakatipu district, sharing his records with me and joining me on many expeditions to search for the two species in the Wakatipu Basin. I thank John Dugdale for records from Landcare Research Ltd, Martin Honey for records from the British Natural History Museum, Rosemary Gilbert for the Auckland Museum records, Dr John Ward for Canterbury Museum records, and Pamela Lovis for records in the Museum of New Zealand. I thank Joe Firmin for references and general encouragement. Further I thank Peter Egerton of the Cromwell Mining Centre for permission and assistance in running a light-trap for a year at the centre. I thank Dr John Ward, Andrew Townsend, Eric Edwards, John Dugdale, Bruce McKinlay, and two anonymous referees for useful comments on a draft of this paper.

7. References

Clarke, C.E. 1933: The Lepidoptera of the Te Anau-Manapouri Lakes Districts. *Transactions & Proceedings of the New Zealand Institute 63*: 112–132.

Craw, R.C. 1986: Review of the genus *Notoreas* (sensu auctorum) (Lepidoptera: Geometridae; Larentiinae*). New Zealand Journal of Zoology 13*: 131–140.

Davies, T.H. 1973: List of Lepidoptera collected in areas surrounding Hastings and Napier. *New Zealand Entomologist 5(2)*: 204–216.

Davies, T.H. 1986: *A checklist of the Arthropoda from Hawkes Bay, New Zealand*. Royal Forest & Bird Protection Society, Wellington.

Department of Conservation, Otago Conservancy 1999: Otago Conservation Management Strategy. Vol. 1–3. *Otago Conservancy CMS Series No. 7*. Department of Conservation, Dunedin.

Dopson, S.R.; de Lange, P.J.; Ogle, C.C.; Rance, B.D.; Courtney, S.P; Molloy, J. 1999: The conservation requirements of New Zealand's nationally threatened vascular plants.

Threatened Species Occasional Publication No. 13. Department of Conservation, Wellington.

Dugdale, J.S. 1988: Lepidoptera—annotated catalogue, and keys to family-group taxa. *Fauna of New Zealand 14*. DSIR, Auckland.

Fry, R.; Lonsdale, D. 1991: Habitat conservation for insects—A neglected Green Issue. *The Amateur Entomologist Vol. 21*. 262 p.

Guenee, A. 1868: New species &c of heterocerous Lepidoptera from Canterbury, New Zealand collected by Mr R.W.Fereday. *Entomologists' Monthly Magazine 5*: 1–6, 38–43, 61–65, 92–95.

Howes, W.G. 1946: Lepidoptera collecting at Homer, with descriptions of new species. *Transactions & Proceedings of the New Zealand Institute 76(2)*: 139–147.

Hudson, G.V. 1898: New Zealand moths and butterflies (macro-lepidoptera). West, Newman & Co, London. 144 p.

Hudson, G.V. 1928: The butterflies and moths of New Zealand. Ferguson & Osborn, Wellington.

Hudson, G.V. 1939: A supplement to the butterflies and moths of New Zealand. Ferguson & Osborn, Wellington.

Kirby, P. 1992: Habitat Management for Invertebrates: A Practical Handbook. RSPB. 150 p.

Lewis, J.H. 1901: Lepidoptera of Mt Ida. *Transactions & Proceedings of the New Zealand Institute 33*: 186–187.

Logan, M.C.; Holloway, J.E. 1934: Plant succession on the Oreti River sand dunes. *Transactions & Proceedings of the Royal Society of New Zealand 64 (2)*: 122–174.

Meyrick, E. 1884: A monograph of the New Zealand Geometrina. *Transactions & Proceedings of the New Zealand Institute 16*: 49–113.

Molloy, J.; Davis, A. 1994: Setting priorities for the conservation of New Zealand's threatened plants and animals. 2nd ed. Department of Conservation, Wellington.

New, T. 1990: Directory of Lepidoptera conservation projects. IUCN/SSC Lepidoptera Specialist Group, . 80 p.

New, T. 1997: Are Lepidoptera an effective "umbrella group" for biodiversity conservation? *Journal of Insect Conservation 1*: 5–12.

Patrick, B.H. 1989: Lepidoptera of Central Otago saltpans. Department of Conservation, Dunedin. 43 p.

Patrick, B.H. 1994a: Valley floor Lepidoptera of Central Otago. Department of Conservation, Dunedin. Miscellaneous Series No.19. 54 p.

Patrick, B.H. 1994b: Lepidoptera of the southern plains and coast of New Zealand. Department of Conservation, Dunedin. *Miscellaneous Series No. 17*. 43 p.

Patrick, B.H.; Dugdale, J.S. 2000: Conservation status of the New Zealand Lepidoptera. *Science for conservation 136*. Department of Conservation, Wellington.

Patrick, B.H.; Lyford, B.M.; Ward, J.B.; Barratt, B.I.P. 1992: Lepidoptera and other insects of the Rastus Burn Basin, The Remarkables, Otago. *Journal of the Royal Society of New Zealand 22(4)*: 265–278.

Peat, N.; Patrick, B.H. 1995: Wild Dunedin. University of Otago Press, Dunedin. 144 p.

Philpott, A. 1901: Catalogue of Southland Lepidoptera.*Transactions & Proceedings of New Zealand Institute 33*: 167–185

Philpott, A. 1904: Notes on southern Lepidoptera. *Transactions & Proceedings of New Zealand Institute 36*: 161–170.

Philpott, A. 1907: Notes on the protective resemblance in New Zealand moths. *Transactions & Proceedings of the New Zealand Institute 39*: 212–219.

Philpott, A. 1912: Nature Column. *Southland Times,* 2 March 1912, p. 11.

Philpott, A. 1917: A list of the Lepidoptera of Otago. *Transactions & Proceedings of the New Zealand Institute 49*: 195–238.

Prout, L.B. 1939: Geometridae: Fauna Indo-Australica. In Seitz, A., *The Macrolepidoptera of the World (Stuttgart) 12*: 237–292.

Sherley, G. 1989: Important conservation research topics on terrestrial arthropod species in New Zealand. *Science & Research Internal Report No. 53*. Department of Conservation. Wellington.

Skou, P. 1986 : The Geometroid Moths of North Europe. E.J.Brill, Leiden.