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Working Paper No. 100

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Clem Tisdell[2], Clevo Wilson[3]
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The research for ACIAR project 40 has led in part, to the research being carried out in this current series.

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The threatened mahogany glider *Petaurus gracilis.*

This photograph belongs to the Queensland Museum.

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AN INITIAL ASSESSMENT OF POLICIES FOR SAVING A RARE AUSTRALIAN GLIDER: EXPERIMENTAL RESULTS, ECONOMICS AND ECOLOGY

Abstract

Reviews the ecological status of the mahogany glider and describes its distribution, habitat and abundance, life history and threats to it. Three serial surveys of Brisbane residents provide data on the knowledge of respondents about the mahogany glider. The results provide information about the attitudes of respondents to the mahogany glider, to its conservation and relevant public policies and about variations in these factors as the knowledge of participants of the mahogany glider alters. Similarly data is provided and analysed about the willingness to pay of respondents to conserve the mahogany glider. Population viability analysis is applied to estimate the required habitat area for a minimum viable population of the mahogany glider to ensure at least a 95% probability of its survival for 100 years. Places are identified in Queensland where the requisite minimum area of critical habitat can be conserved. Using the survey results as a basis, the likely willingness of groups of Australians to pay for the conservation of the mahogany glider is estimated and consequently their willingness to pay for the minimum required area of its habitat. Methods for estimating the cost of protecting this habitat are outlined. Australia-wide benefits seem to exceed the costs. Establishing a national park containing the minimum viable population of the mahogany glider is an appealing management option. This would also be beneficial in conserving other endangered wildlife species. Therefore, additional economic benefits to those estimated on account of the mahogany glider itself can be obtained.

Keywords: Conservation policies; contingent valuation; knowledge; Mahogany glider *Petaurus gracilis*; population viability analysis; social cost-benefit analysis

AN INITIAL ASSESSMENT OF POLICIES FOR SAVING A RARE AUSTRALIAN GLIDER: EXPERIMENTAL RESULTS, ECONOMICS AND ECOLOGY

1. Introduction

The mahogany glider *Petaurus gracilis* is one of Australia's rarest wildlife species and is considered to be highly endangered (Strahan, 2000, p. 232-233). It is confined to a comparatively small area of land located in the coastal belt of Northeast Queensland between Townsville and Cairns. Most of its remaining habitat is on state (crown) land that is leased to private entities. But some is freehold land (private property) and some is state land used for state purposes e.g. forestry. It is a normal expectation that state leases will be renewed when leases fall due for renewal. No protected area has been set aside within the present range of the mahogany glider to increase the likelihood of the survival of the mahogany glider. However tighter controls on clearing of vegetation on land in Queensland may help to preserve the glider's habitat on private and leasehold land.

The mahogany glider is so elusive and rare that it was for several decades believed to be extinct but it was re-discovered in 1989. Europeans first collected and described it in the 1880s.

The species appears to have little or no economic use value. Prospects for using it for tourist purposes in its area of natural habitat may be low because it is nocturnal, relatively small in size and difficult to locate. Thus its economic value appears to consist almost entirely of its non-use economic values, particularly its existence value. There may be some use values for zoos using infrared lighting but such use is highly regulated.

This article is primarily intended to address the question of whether there is likely to be a net social economic benefit in adopting particular policy measures to protect the mahogany glider. Would it be economic, for example, to set aside a portion of present area of habitat of the mahogany glider as a protected area in order to give the species a high chance of survival for the next 100 years? That is the main question considered in this paper. Data for estimating willingness to pay for the conservation of the mahogany glider are obtained from surveys of a sample of Brisbane residents. These are extrapolated for larger Australian populations and their total willingness to pay is compared to the total value of land area that would be

required to ensure a high probability of survival of the mahogany glider for the next 100 years.

However, first the ecological status of the mahogany glider and the nature of the three serial surveys of a sample of Brisbane residents is described and the way in which the knowledge of respondents about the mahogany glider changed as a result of survey procedures is specified. Attitudes of the respondents to the mahogany glider, its conservation and policies for this are outlined and compared across the surveys. The way in which the stated willingness of respondents to pay varies with the three surveys is described and possible reasons for the variations are suggested.

The article then uses population viability analyses to estimate the required area of habitat needed to conserve a minimum viable population of the mahogany glider. A corresponding area consisting mostly of state leasehold land is identified. Extrapolations are made from the survey data to estimate the willingness to pay of groups of Australians for the conservation of the mahogany glider and how much per hectare they would be prepared to pay to protect sufficient area of habitat to sustain a minimum viable population of the mahogany glider. Ways of estimating the economic cost of this habitat preservation are considered, and there is a general discussion of issues involved in estimating benefits, costs and management of mahogany glider populations.

2. An Overview of the Ecological Status of the Mahogany Glider

Description

The mahogany glider, a marsupial mammal, was first officially described in 1883 by the Cambridge-educated palaeontologist and then-director of the Queensland Museum, Charles De Vis (De Vis, 1883; Mather, 1986; Van Dyck, 1993). Despite being a genetically distinct species (Colgan and Flannery, 1992; Van Dyck, 1993), the mahogany glider's taxonomic status and distribution was initially so poorly known that for years it was considered a northern subspecies of the squirrel glider *Petauraus norfolcensis* (Thomas, 1888; Iredale and Troughton, 1934; Fleay, 1947; Marlow, 1963; Van Dyck, 1993).

This species is different from the other species in the *Petaurus* genus and can be distinguished from the squirrel glider by its larger size, long, relatively short-haired tail and

buff to mahogany-brown belly (Van Dyck, 1993). Upperparts vary from mahogany brown to smoky grey with patches of yellow-brown on shoulders, flanks and rump (Menkhorst, 2001). It has large, brown eyes, a pointed snout and hairless ears. The patagium, a membrane extending from its wrist to its heel, converts the gliders's body into an effective, low-aspect-ratio airfoil that allows the animal to travel from tree to tree at the greatest possible horizontal distance with the least loss in altitude (Jackson, 2000a).

Interest in the mahogany glider was stirred when it was rediscovered in 1989. Following the finding of previously unregistered museum specimens that matched De Vis' description of the species (Van Dyck, 1990) and the location of living representatives on freehold land being extensively cleared for agriculture at Barrett's Lagoon near Tully in Northeast Queensland (Van Dyck, 1992), the precarious existence of the mahogany glider captured public attention and prompted a call for its conservation. Subsequently, the local government issued a suspension on land clearing in areas identified as critical habitats. However, clearing of peripheral lands that are still used by the glider have been reported to continue (CAFNEC, 2003).

The mahogany glider has since been recognised as one of Australia's most threatened mammals, and is classified as endangered under the Queensland *Nature Conservation Act 1992* and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (QPWS, 2001).

Distribution, Habitat and Abundance

The Mahogany glider's geographic range is restricted to the Wet Tropics bioregion, in the the shires of Cardwell and Hinchinbrook, Northeast Queensland. It has only been recorded in a narrrow band of medium- to low-elevation forest and woodland areas, extending from the Hull River south of Tully to Crystal Creek south of Ingham (as shown in Figure 1 below) (Van Dyck, 1993; EPA, 2002d; Jackson, 2003). This distribution occurs along a north to south distance of 110 to 130 km (Jackson and Claridge, 1999; Jackson, 2003), encapsulating an area of approximately 720 kilometre-square (Van Dyck, 1993; Blackman et al., 1994; Jackson, 1998; Menkhorst, 2001). These lands are mostly leasehold and state forest land, and to a lesser extent freehold land (EPA, 2002a; EPA, 2002b).

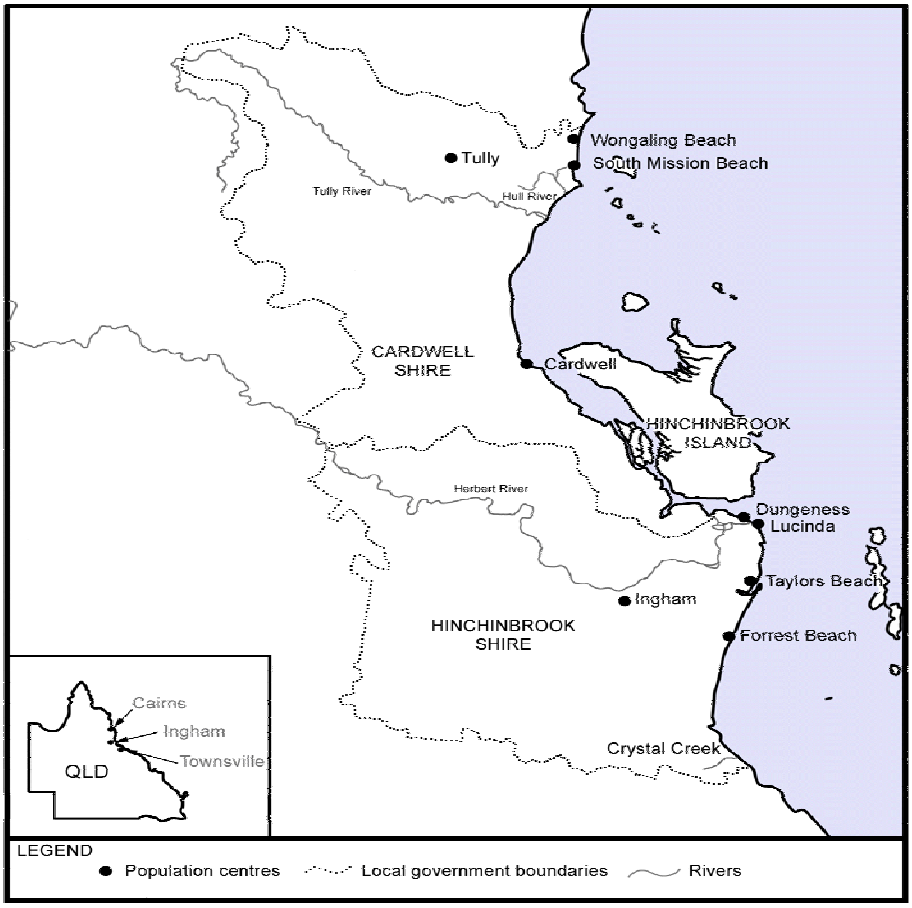

Figure 1: Cardwell and Hinchinbrook Shires in the Wet Tropics bioregion of Queensland, where the mahogany glider is found

Habitats critical for the mahogany glider consist of mixed-species open woodlands and grasstree *Xanthorrhoea johnsonii* woodlands containing stands of eucalypts, bloodwood, melaleuca and acacias (Van Dyck, 1993; Jackson, 2000b). White siris *Albizia procera* trees have also been found to be an important species for this glider, particularly when few other species are in flower (Jackson and Claridge, 1999; QPWS, 2001). These gliders appear to prefer areas with open canopies and poorly developed understories, as opposed to thick forests (NRM, 2001; Jackson, 2000b). They were found to avoid rainforest and rainforest regrowth, although they have been seen to pass through them to get to suitable habitat (QPWS, 2001). Areas where the glider occurs are also characterised by very high seasonal rainfall (Van Dyck, 1993).

The glider is a highly mobile species and relies on continuous forest or woodland cover to range freely (QPWS, 2001). However, suitable habitats are highly fragmented, and have been reduced to approximately 20 percent of their original extent and are at risk of further clearing, particularly for agricultural crops like sugarcane and bananas (QPWS, 2001). In fact, the largest continuous piece of land deemed a critical habitat lies in the middle of cultivated land southwest of Ingham (EPA, 2002a; EPA, 2002b; EPA, 2002c). Non-rainforest areas like those which house the glider, according to some regional environmental organizations and some scientists, have not been given adequate protection (CAFNEC, 2003)[1].

At present there are no very reliable data relating to the mahogany glider's abundance. Due to the mahogany glider's rarity and elusive and virtually silent nature (Van Dyck, 1995), the task of estimating its population size has been made exceedingly difficult. The IUCN Redlist (IUCN, 2002) provides an estimate of less than 2500 remaining individuals. However the species has been on the decline. Van Dyck (1993) suggests that the range and abundance of the population, based on habitat loss, has fallen by as much as 80 percent over the past 50 years. Recent years have seen the clearing of a number of recorded mahogany glider sites (QPWS, 2001) and the relegation of the species to severely fragmented pockets of suitable habitats (Eyre, 1993; Lyon, 1993; Blackman et al., 1994; Jackson, 1998). A study by Jackson (2000c) indicated that the mahogany glider population density in a fragmented habitat was two-thirds the population density in a continuous habitat.

Recorded occurrences in Conservation Reserves

There are two reserve areas where the glider has been recorded in recent times. In Lumholz National Park (18°24'30"S, 145°46'10"E), a glider was observed near the rainforest transition site by the Herbert River (Van Dyck, 1993). In Edmund Kennedy National Park (18°12'04"S, 145°59'14"E), the glider was not seen but its call was heard, and it was thought to have moved from this site into adjacent tea-tree swamp (Van Dyck, 1993). However, there is no protected area within the remaining area of the critical habitat of the mahogany glider.

Life History and Ecology

The mahogany glider is nocturnal and glides at night to feed in trees and ocassionally forages on the ground (QPWS, 2001). They use the hollows of trees as dens for sleeping and raising their young (Jackson, 2000d). They appear socially monogamous (Jackson, 2000d) and have

litter sizes of 1.55 young on average (QPWS, 2001). Up to a dozen dens may be used in a single season by individuals or pairs (Van Dyck, 1993; Jackson, 2000d). This glider feeds on a wide range of seasonally available foods such as nectar, pollen, fruit, arthropods, arachnids, wattle exudates and honeydew (Jackson, 2000e; QPWS, 2001). Food sources (not reported for other petaurids) are also consumed by the glider: lichens, green tree ants and the sap of the White siris (Van Dyck, 1993; Jackson, 2000e). These gliders take up home ranges of up to 23.15 hectares per mated pair (Dettman et al., 1995; Jackson, 2002d). Predators of the mahogany glider include the rufous, sooty and masked owls, and scrub pythons (Van Dyck, 1993; Jackson, 1998).

Threats

Habitat loss combined with fragmentation is the major threat to the mahogany glider. Habitat loss and fragmentation occurs due to clearing of woodlands for pasture; banana, sugar cane and pineapples; timber; and drainage of woodlands and melaleuca wetlands for aquaculture (QPWS, 2001; IUCN, 2002; Animal Info, 2003).

The reduced occurrence of fire also adversely affects the mahogany glider, because the rapid transition of open forests or woodlands to closed forest dominated by rainforest species is unsuitable for the glider (Dettman et al., 1995; Stanton, 1998; Bowman et al. 2001). Australian Aborigines systematically practised burning of grassland and woodland, a procedure favourable to maintaining habitats suitable for the mahogany glider in its population distribution (Bowman, 1998).

A population viability analysis by Jackson (1999a) suggests that a minimum area of 8000 hectares is needed for a population of 800 adult individuals in order to maintain a viable population of mahogany gliders. Smaller areas than this and ones that have smaller and isolated populations have a lower chance of ensuring long-term survival of the species unless habitats are linked and populations dispersed between fragments (QPWS, 2001). Therefore, isolated habitats retained by landholders if connected by vegetational corridors could help reduce the threat of population extinctions (QPWS, 2001).

Other Threatened Species and Ecosystems Found in the Same Area as the Mahogany Glider

Efforts to conserve the mahogany glider may indirectly benefit the other species and ecosystems that spatially coincide with that of the mahogany glider. A group of 28 such faunal and floral species and regional ecosystems have been listed in the *Mahogany Glider Recovery Plan 2000-2004* (QPWS, 2001). Among these are threatened species of various taxa such as the Apollo jewel butterfly *Hypochrysops apollo apollo* and the attendant ant plant *Myrmecodia beccarii*, the Southern cassowary *Casuarius casuarius*, the waterfall frog *Litoria nannotus* and the swamp orchid *Phaius tancarvilleae* (QPWS, 2001). Endangered ecosystems include the swamp paperbark and rainforest complex, the red tea tree riparian open forest and the forest red gum woodland (QPWS, 2001). Given that some of these other species and ecosystems have economic value, the economic value of conserving habitat of the mahogany glider will exceed that attributed to this glider.

3. Nature of Surveys, the Experiment, and the Knowledge of Respondents of the Mahogany Glider

Data for the study was gathered by means of three questionnaire-based surveys during the period of July to September, 2002. These surveys were designed to determine the Brisbane public's knowledge of the mahogany glider, their attitude towards and willingness to pay for its conservation under different knowledge and experiential conditions. This information was gathered as part of a broader survey of the attitudes of the sample and their WTP for conservation of a range of Australian tropical wildlife species. However, only results that are pertinent to the mahogany glider are reported here.

Using mainly letterbox-dropped circulars distributed in varied suburbs of Brisbane with differing socio-economic characteristics, a survey sample of 204 responding participants was obtained. The provided circular was an invitation to participate in surveys on the use and conservation of Australia's tropical resources, to be conducted at the University of Queensland. The real nature and objectives of the experimental surveys were withheld to avoid bias. As an incentive, it was mentioned that participants would be offered A$20.00 and an opportunity to win A$200.00 as well as a public lecture and refreshments. Responding participants were selected on a first-come-first-served basis according to the age distribution of Brisbane city so that the sample would be reasonably representative of Brisbane residents.

Participants were divided into five groups of about 40 individuals to attend survey sessions of approximately two hours with a 15-minute tea break. Four groups were requested to attend sessions held at the University of Queensland— two groups during the working week, two during the weekend— and one group at a church hall on a Sunday. This arrangement was designed to accommodate the participation of employed persons and provide flexibility for other participants.

In the first stage, lasting an hour, of the initial survey session, participants filled out a structured questionnaire (Survey I) to gather background information and their initial knowledge of 24 Australian wildlife species including the mahogany glider. The participants were also asked for their WTP for the conservation of some species assuming that they were to give one-off donations. The mahogany glider was one of the species selected for this purpose. A tea break followed.

The second stage (second hour) commenced with an interesting presentation given by Dr. Steven Van Dyck, Curator of Mammals and Birds at the Queensland Museum, primarily about the mahogany glider. Coloured photo brochures describing the species in the survey, their geographical range, current status and other pertinent information were then handed out to participants. Approximately the same amount of factual background information was provided on each species and normative statements were avoided. The participants were asked to take the brochure home and were requested to read it before completing and returning (in postage pre-paid envelope) a second questionnaire, Survey II, one containing several overlapping questions with Survey I. When compared to Survey I, answers to the overlapping questions in Survey II provided information on changes in the respondents' knowledge of the various wildlife species, and alterations in their attitudes and support for the conservation of species.

One of the questions asked in Survey II was whether the participants would like to take a trip to the David Fleay Wildlife Park in the Gold Coast if provided with free entry tickets. More than half the respondents (119 of them) responded positively, and utilised the free tickets given to enter the wildlife park.

This park is managed as an environmental education facility by the Queensland Parks and Wildlife Service (QPWS), and displays local native animals as well as rare and threatened species (EPA, 2003b). The park also has breeding programs for rare and threatened Queensland species (EPA, 2003b). At the park, the participants had the opportunity to see several rare and endangered species described in their questionnaires and coloured brochure, such as the mahogany glider. At the end of their tour of the wildlife park, the participants were asked to fill out a third questionnaire (Survey III). Survey III repeated the one-off willingness-to-pay question for conservation of the mahogany glider posed in the previous two survey questionnaires. The purpose of this was to gauge any change in conservation attitudes and support for the conservation of species now that the participants have had first-hand experience of some of these animals.

Although all the 204 persons in the sample participated in Survey I and II, only 119 visited Fleay's Wildlife Park and completed Survey III. One of the reasons presumably was that they had to travel some distance from Brisbane at their own expense to visit Fleay's.

In the initial survey, only 48 percent of respondents stated that they had any knowledge of the mahogany glider. Most (52%) indicated no knowledge of this species. On a scale of 'very good', 'good' and 'poor', only 13 percent of respondents rated their knowledge of the mahogany glider as very good or good, over 35 percent said they had poor knowledge of it.

In Survey II, 95 percent of respondents stated that they knew the mahogany glider, and 5 percent did not respond to the question. Most respondents (74%) considered that their knowledge of the mahogany glider was now very good or good with only 23 percent stating that it was poor. Hence, there was a substantial increase in the stated degree of knowledge of this species by participants, presumably mainly because of the illustrated lecture by Dr. Steven Van Dyck concentrating on the mahogany glider.

Of the 119 persons from the sample who visited Fleay's Wildlife Park, 99 stated that they had seen the mahogany glider on their visit. They, therefore, had the experience of seeing it 'in the flesh'. Against this background of changes in the knowledge of and experience with the mahogany glider of participants, it is interesting to consider variations in the attitude of respondents to the conservation of the mahogany glider and to public policies to conserve it.

A discussion of this matter will be followed by consideration of how the average willingness of respondents to pay for the conservation of the mahogany glider varied across the three surveys.

4. Attitudes of Respondents to the Mahogany Glider, its Conservation and Relevant Public Policies

Respondents were asked whether they strongly like, like, dislike, strongly dislike or are uncertain of their feelings towards the mahogany glider. The distribution of the results in Survey I and Survey II are set out in Table 1. It is clear that a large proportion of respondents who had little or even no knowledge of the mahogany glider said they strongly like or like it rather than saying they are uncertain about their feelings towards it. The reason is unclear. We can, however, see that the number of those who were uncertain of their feelings about the mahogany glider declined to a great extent between Survey I and II. Those who said they liked or strongly liked this glider rose from 79.4% of the sample to 91.7% of the sample. Weighting 'strongly like' as 2, 'like' as 1, 'dislike' as –1, 'strongly dislike' as –2, and 'uncertain' and no response as zero, the weighted average of feelings towards the mahogany glider increased from 1.14 in Survey I to 1.4 in Survey II.

Table 1:

Feelings expressed by respondents about the mahogany glider

Distribution of responses

Attitudes	**Weights**	**Survey I**		**Survey II**	
		No. of respondents	**Relative freq. (%)**	**No. of respondents**	**Relative freq. (%)**
Strongly like	2	80	39.2	101	49.2
Like	1	82	40.2	86	42.2
Dislike	-1	2	1.0	3	1.5
Strongly dislike	-2	1	0.5	0	0
Uncertain	0	33	16.2	7	3.4
Non-responses	0	6	2.9	7	3.4
Total		*204*	*100*	*204*	*100*

Weighted averages— Survey I: 1.17; Survey II: 1.40

Respondents were asked in Survey I and II whether they were in favour of the survival of the mahogany glider. The distribution of responses is set out in Table 2. Note that a much higher

proportion of respondents are in favour of the survival of the mahogany glider than the percentage that strongly like or like it. One does not have to like a species to favour its survival. The percentage of respondents favouring survival of the species rose between Survey I and II. There is very strong support for its survival in both surveys.

Table 2:

Distribution of responses to the question of whether respondents favour the survival of the mahogany glider

Response	Survey I		Survey II	
	No. of respondents	Relative freq. (%)	No. of respondents	Relative freq. (%)
Yes	195	95.6	198	97.1
No	1	0.5	2	1.0
Indifferent	4	2.0	0	0.0
Others	4	2.0	4	2.0
Total	*204*	*100*	*204*	*100*

In the third survey, participants were asked whether as a result of the whole survey their support for the continued existence of the mahogany glider had increased, decreased or had remained the same. Almost a half said it had increased, just under a half said it had remained constant, and no one indicated that their support had decreased (see Table 3). The results show the sensitivity of participants to the provision of information and their experience.

Table 3:

Nature of changes in support by respondents for the continued existence of the mahogany glider as a result of the whole survey experience

Distribution of responses

Response	Survey III	
	No. of respondents	Relative freq. (%)
Increased	58	48.7
Decreased	0	0.0
Remained constant	55	46.2
No response	6	5.0
Total	*119*	*100*

Survey participants were asked if the Queensland government should do much more than now to ensure the survival of the glider. The distribution of responses of participants in Survey I and Survey II are summarised in Table 4. Just under two-thirds of participants said 'Yes' in Survey I and almost a third were unsure. In the second survey the number saying that the Queensland Government should do more to ensure the survival of the mahogany glider rose to 85 percent and those that were unsure more than halved.

Table 4:

Distribution of responses to the question of whether the Queensland Government should do much more than now to ensure the survival of the mahogany glider

Response	**Survey I**		**Survey II**	
	No. of respondents	**Relative freq. (%)**	**No. of respondents**	**Relative freq. (%)**
Yes	133	65.2	173	84.8
No	1	0.5	0	0
Unsure	64	31.4	27	13.2
N/r and others	6	2.9	4	2.0
Total	*204*	*100*	*204*	*100*

As can be seen from Table 5 there was strong support for putting more of this glider's habitat into protected areas or for jointly doing this together with restrictions on clearing of its habitat on private lands. This was supported by more than 80 percent of respondents in Survey I and over 90 percent of respondents in Survey II (See Table 5).

Table 5:

Support for strategies by Queensland Government to assist the survival of the mahogany glider. Distribution of responses

Do you think the QLD government should do any of the following to assist the survival of this species?	Survey I		Survey II	
	No. of respondents	Relative freq. (%)	No. of respondents	Relative freq. (%)
(a) Put more of its habitat into protected areas (e.g. National Parks)	84	41.2	66	32.4
(b) Ban the further clearing of their habitat on private land (e.g. farm land)	24	11.8	12	5.9
Both (a) and (b)	82	40.2	120	58.8
N/r and others	14	6.9	6	2.9
Total	*204*	*100*	*204*	*100*

Most respondents were in favour of a public campaign to gather finance and other support to conserve glider habitat. Support for this increased noticeably in Survey II, as can be seen from Table 6.

Table 6:

Distribution of responses to the question 'Would you favour a public campaign to gather financial and other support for the conservation of the habitat of the species?'

Response	Survey I		Survey II	
	No. of respondents	Relative freq. (%)	No. of respondents	Relative freq. (%)
Yes	135	66.2	172	84.3
No	9	4.4	1	0.5
Unsure	55	27.0	28	13.7
N/r and others	5	2.5	3	1.5
Total	*204*	*100*	*204*	*100*

5. Respondents' Willingness to Pay to Conserve the Mahogany Glider

Participants in the three surveys were asked: "If you were asked for a **one-off** donation for a campaign to save the mahogany glider designed to increase public awareness and secure land against clearing, how much would you contribute?"

All the respondents, that is, 204 persons in Survey I and II and 119 in Survey III responded to this question. The pattern of average willingness to pay per person can be seen from Figure 2.

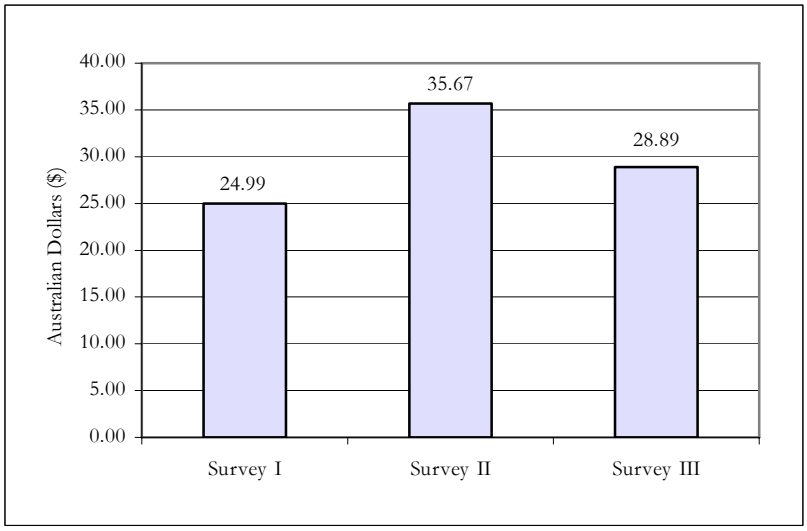

Figure 2: Average willingness of respondents to pay for the conservation of the mahogany glider: Surveys I to III

There was a substantial rise in willingness to pay in Survey II compared to Survey I and then it fell in Survey III but still remained above its value in Survey I when participants had far less knowledge of the mahogany glider. The larger rise between Survey I and II can be largely attributed to the very interesting illustrated lecture given to participants by Dr. Van Dyck. This provided them with considerable information about the mahogany glider and was presented in a stimulating manner. By the time of Survey III the strong stimulus provided by Dr. Van Dyck's lecture had subsided in its effect but had not been eliminated. In addition some extra stimulus was provided to those participants who visited Fleay's Wildlife Park by the visit itself.

While it is difficult to generalise from these results, they suggest that communication providing extra information and giving a stimulating favourable impression to individuals of a species is likely to raise their stated willingness to pay for its conservation very considerably. In the absence of further significant stimulation, their stated willingness to pay to conserve the species falls and approaches its previous level but remains above it. So a typical pattern could be of the form indicated in Figure 3.

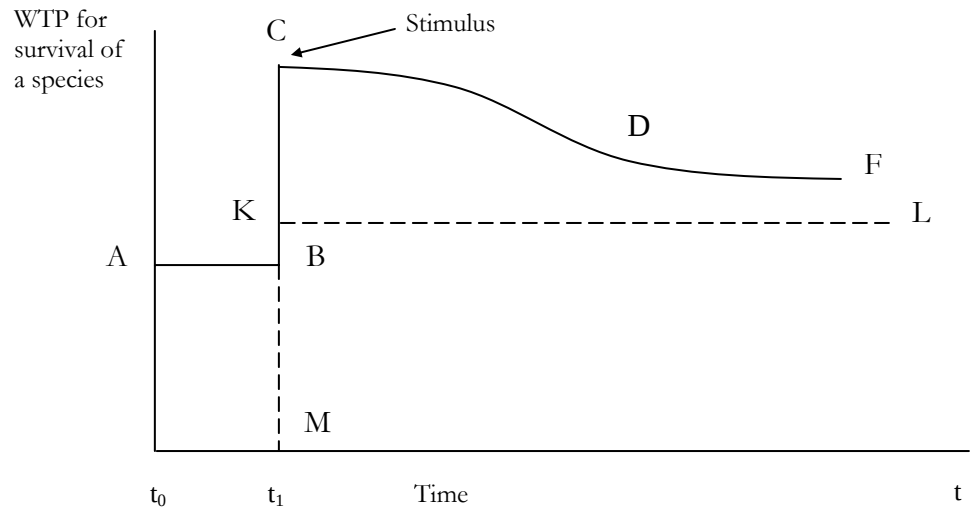

Figure 3: A hypothetical curve of WTP for the conservation of a species as a function of time and in response to a one-off stimulus providing information/communications about the target species

In Figure 3, initially the WTP of a group of individuals is constant as a function of time shown by the line AB but a communication stimulus is administered at t_1. This causes the average WTP of the group to jump from B to C. In the absence of further stimulation there is a drop off in average WTP that may typically result in a curve like that shown by CDF.

This indicates that contingent valuation figures are likely to be sensitive to communication or experiential stimuli and that the effects of those stimuli decay with the elapse of time. In such circumstances, it is difficult to know what the true or real WTP of individuals precisely is and one can even doubt that it exists. This is of policy relevance because the difference between WTP immediately following favourable stimulation of individuals is likely to be quite different from that prior to the stimulus and at a much later time after cessation of the stimulus. It might be tempting to say that KM is the true WTP because it allows for subsidence of emotion and short-term psychological effects from the stimulus, and, therefore, represents greater rationality. But the attainment of unbounded rationality may well be an impossibility because as new external stimuli are received by individuals, they crowd out the effects of previous stimuli and individuals have only limited control over the stimuli they receive.

As pointed out by Spash (2002), it is extraordinarily difficult (possibly virtually impossible) to provide information that has a neutral effect on preferences of recipients of this information, even though one can clearly take steps to reduce this influence. This is supported by the theories of Ajzen and Driver (1992) and Ajzen et al. (1996). The presentation of Dr. Steven Van Dyck about the mahogany glider was, apart from being very informative, possibly quite influential in altering the preferences of recipients about this species. On average, there was a substantial rise in willingness to pay for conservation of this species in Survey II compared to Survey I.

It is interesting to observe the relationship between the participants' stated degree of knowledge of the mahogany glider and their WTP for its survival. Analysis of the survey data indicates that on average, this WTP rises with the stated degree of knowledge that participants have of the mahogany glider. For example in Survey I, those who stated that their knowledge of the mahogany glider is very good or good were prepared to make a one-off payment for its survival of $31.20, those who said their knowledge was poor were prepared to pay $29.50 and those who did not indicate any knowledge were prepared to pay $14.80. In Survey II a similar pattern is revealed if two outliers are removed. It should furthermore be observed that individuals who did not indicate any knowledge of the mahogany glider were, despite this, willing to contribute to its continuing existence although their payments were less than half of the above two categories.

While these relationships are interesting, we cannot conclude that they are entirely due to the provision of information. There is an interdependence consideration. Those who have an intrinsic interest in nature conservation (and particularly in this case the survival of the mahogany glider) are probably more likely to collect information about it and be more receptive to information received about it. Learning depends to some extent on the motivation or the set of individuals. Information is filtered, discarded or retained by individuals in accordance with their motivations, which of course may not be static themselves. Economists cannot avoid considering such psychological issues if they want to use WTP data for policy purposes.

It is interesting to consider the responses of respondents about the effects of their visit to Fleay's on their willingness to support the conservation of the mahogany glider financially or

otherwise. The distribution of results is shown in Table 7. Just over a third of respondents said that their willingness to support the conservation of the mahogany glider increased as a result of their visit. For most, however, their stated support remained unchanged. However, in one case the support declined. This person saw the glider and seems to have found it less impressive than expected.

Table 7:

Reported change in support for conservation of the mahogany glider as a result of respondents' visit to Fleay's. Distribution of responses

Response	**Survey III**	
	No. of respondents	**Relative freq. (%)**
Increased	43	36.1
Decreased	1	0.8
Remained constant	64	53.8
No response	11	9.2
Total	*119*	*100*

Of the 99 persons who saw the glider at Fleay's more than a third found it to be more impressive than expected, more than half found that it was about as expected and 5 percent found it less impressive than anticipated. The distribution of results is summarised in Table 8.

Table 8:

Impressions of those who saw the mahogany glider at Fleay's. Distribution of responses

Response	**Survey III**	
	No. of respondents	**Relative freq. (%)**
Less impressive	5	5.1
More impressive	36	36.4
About as expected	58	58.6
Total	*99*	*100*

Those who saw the glider at Fleay's were more likely to say that their willingness to support the conservation of the mahogany glider financially or otherwise increased as a result of their visit than those who did not see it. However this was not backed up by WTP data from the 99 respondents who answered all the questions about WTP in the three surveys. In fact, those

who saw the glider were prepared to pay less on average in Survey III for its conservation than in Survey II (see Figure 4). By contrast, the WTP amount in Survey III increased for those who did not see the glider (see Figure 5). The reasons are unclear but the result may indicate a shortcoming in the sample in Survey III.

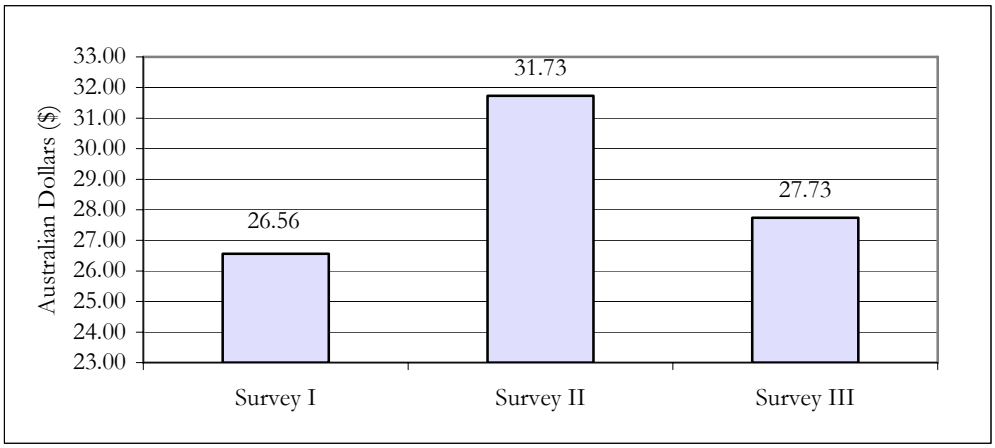

Figure 4: **Willingness to pay for the conservation of the mahogany glider, Surveys I to III, of the 77 participants who saw the glider at Fleay's Nature Reserve *and* had stated clearly their WTP in all three surveys**

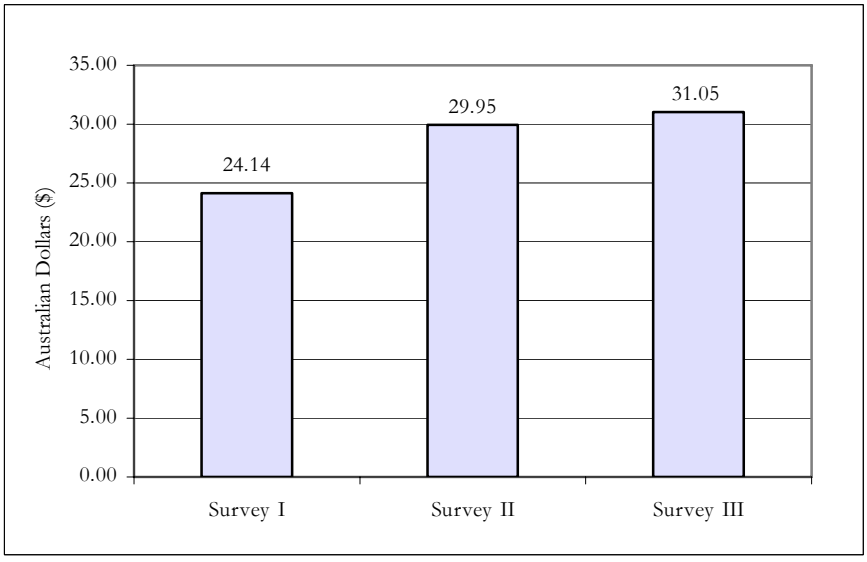

Figure 5: **Willingness to pay for the conservation of the mahogany glider, Surveys I to III, of the 22 participants who did not see the glider at Fleay's Wildlife Park *and* had stated clearly their WTP in all three surveys**

It was found that average WTP for the conservation of the mahogany glider rose with the level of education of respondents (Figure 6). It also did this for high levels of income (see Figure 7).

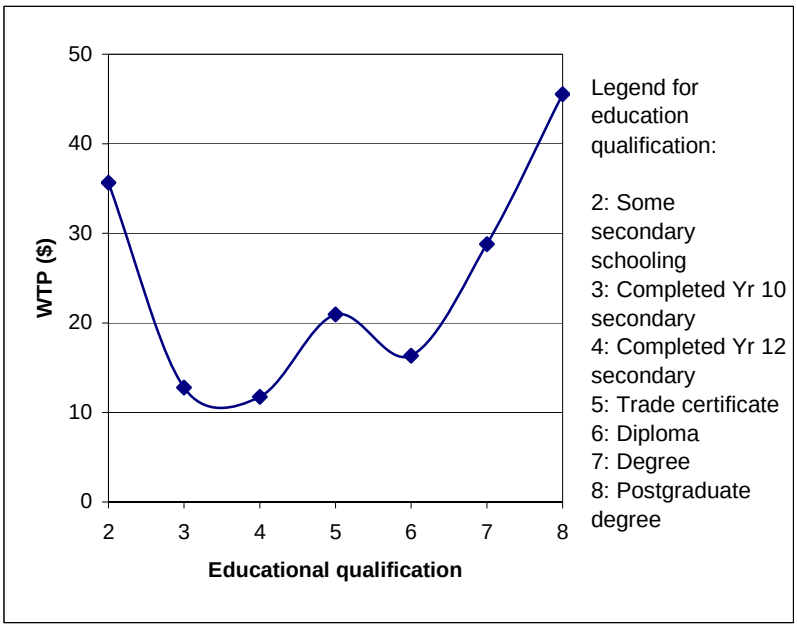

Figure 6: Mean willingness to pay for conservation for the mahogany glider across all three surveys in relation to level of education

Sample selection: Includes all respondents (96) who gave definite WTP values in all three surveys, and answered education qualification question clearly and unambiguously

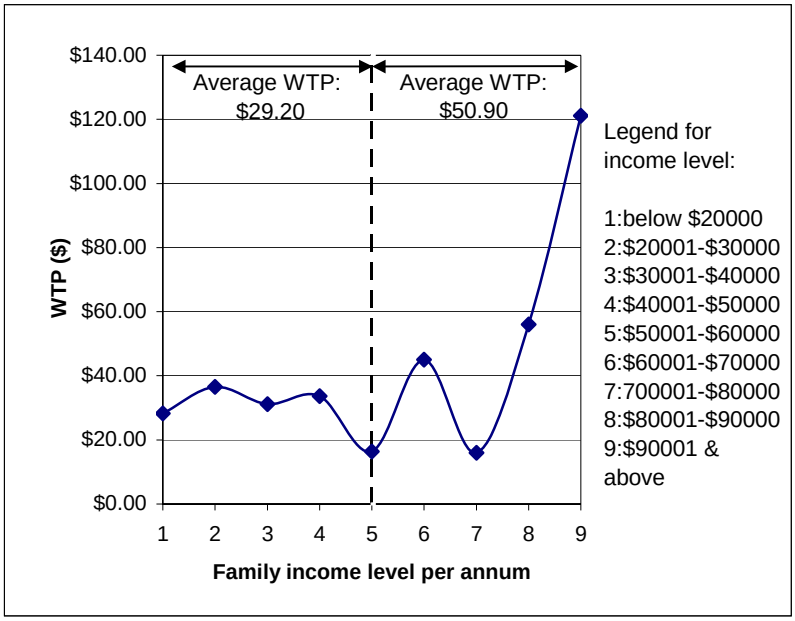

Figure 7: Mean willingness to pay for the conservation of the mahogany glider across all three surveys in relation to level of income

Sample selection: Includes all respondents (99) who gave definite WTP values in all three surveys, and answered level of income question

In order to see if WTP for the conservation of the mahogany glider might exceed the cost of policies to increase its chances of survival, it is necessary to obtain estimates of the aggregate willingness to pay because the continuing survival of the mahogany glider is essentially a pure public good. The extent to which we would be justified in extrapolating the WTP estimates obtained in the experimental surveys is of course open to question. The sample is small in relation to the potentially relevant human populations.

The wider one defines the relevant population, the less representative may be the sample. For example, it may be more representative of the population of Brisbane than Queensland, and of Queensland rather than Australia. Further sampling would be needed to improve the estimates. Also, the question remains open of whether the WTP should be based upon Survey I or say Survey III. Here we shall use the conservative figure of a one-off payment of $25 as obtained in Survey I. The aggregate WTP for the conservation of the mahogany glider by the adult populations of Brisbane, Queensland and Australia will be estimated by assuming that on average all members of these populations would be willing to pay $25 per head. It is

possible that the amounts would be smaller outside Brisbane and in Australian states other than Queensland. These aggregate figures will be used to determine how much Australian populations would be prepared to pay in aggregate to protect the minimum area of habitat required to conserve the mahogany glider. It is now intended to estimate this minimum area of required habitat and then provide the aggregate WTP estimates so that cost-benefit factors can be taken into account.

6. An Assessment of Required Habitat Area for a Minimum Viable Population of the Mahogany Glider Using Population Viability Analysis (PVA)

Mahogany glider habitats are found on state forest reserves, freehold lands and state leasehold lands. The mahogany glider habitat within the bounds of state forest reserves are relatively the safest, as a moratorium on clearing was imposed after the species' discovery (QPWS, 2001). Most mahogany glider habitats however lie outside the existing protected area estate (QPWS, 2001). On some parcels of freehold land, restrictions have been imposed by the QPWS on the clearing of mahogany glider habitat through use of interim conservation orders issued under the *Nature Conservation Act 1992* (QPWS, 2001). On leasehold land, the Department of Natural Resources have acted to restrict tenure conversion and tree clearing in habitat areas (QPWS, 2001).

Nevertheless, in restricting land use or allocating reserves decisions about approximately how much land to set aside must be made. A conserved area should be large enough to support a population size that is viable over the long-term. Judgement on the minimum land area required to ensure viability can be aided by quantitative estimates obtained from a population viability analysis (PVA).

PVA is a modelling tool that helps predict the probability that a species will become extinct over a given time in a particular area and can provide guidelines for selecting management options (Boyce, 1992; Lindenmayer et al., 1993; Goldingray and Possingham, 1995). Defining population viability as a probability of extinction of no more than 5% in 100 years (*cf.* Goldingray and Possingham, 1995; Jackson, 1999), the minimum population size and hence the minimum reserve area for the mahogany glider can be estimated.

PVAs performed by Jackson (1999) using the computer model VORTEX 7.3 indicate that a stable minimum viable population size is 800 individuals. Populations of 400 to 700 individuals also have a lower than 5% chance of extinction in 100 years and a positive growth rate, but still display a decreasing trend in size and could still go extinct after 100 years (Jackson, 1999). Population sizes of 300 individuals and below have greater than 5% chances of extinction in 100 years and negative growth rates and are therefore considered not viable (Jackson, 1999).

Our PVA simulations employing a newer version of VORTEX (Version 9.33) (Miller and Lacy, 2003) and using input data based on the study by Jackson (1999) (see Table 9) reveal similar results, though differing on the size of the probability of extinction value for the 300-individual case (we found a 4% probability of extinction in this case). However, since the 300-individual case lies on the borderline, Jackson's viable/unviable population size cut points are affirmed (Table 10). The stable minimum viable population target of 800 individuals is desirable if the aim is to have less than a 5% probability of extinction of this species within 100 years. On grounds of genetic diversity, it also satisfies the 50/500 rule (Franklin, 1980) that an effective population size has to be above the 500-individual limit to maintain a heterozygosity level high enough after each generation (usually 95% or above) to guarantee the evolutionary potential of the population (see Table 10 for heterozygosity levels).

Table 9:

Life history parameter values of the mahogany glider input to VORTEX 9.33 for PVA (Jackson, 1999)

Parameter		Value	
Inbreeding depression Reproduction EV in concordance with survival EV Lethal equivalents % due to recessive lethals		Yes Yes 3.14 (default value) 50 (default value)	
Breeding system		Monogamous	
Age of first offspring for females and males		2	
Maximum age of reproduction		6	
Maximum number of progeny per year		2	
Sex ratio at birth – in % males		50	
% adult females breeding/EV in % breeding		95/5	
Number of offspring per female per year 0 offspring 1 offspring 2 offspring		 0 54 41	
Mortality of males and females as % Mortality from age 0 to 1/SD Mortality from ages 1 to 2/SD Annual mortality after age 2/SD		 25/5 35/5 20/5	
% males in breeding pool		100	
Start at stable age distribution		Yes	
Initial population size (N)		50-1,000	
Population carrying capacity, K/SD		K=N*1.1/0	
No. of interation	No. of years	100	100

Table 10:

Mahogany glider PVA results from VORTEX 9.33

Initial population size (t=0 years)	Mean final extant population size (t=100 years)	Population growth rate (rate ± standard deviation)	Probability of extinction in 100 years, PE (%)	Final heterozygosity, H (as a % of initial gene diversity)	Median time to extinction in years (for PE> 5%)
Viable for the long term					
1,000	970	0.020±0.079	0	97.92	-
900	843	0.018±0.079	0	97.56	-
800	746	0.017±0.079	0	97.27	-
Viable but likely to become extinct after 100 years					
700	648	0.017±0.081	0	96.81	-
600	505	0.013±0.081	0	96.18	-
500	410	0.012±0.081	0	95.21	-
400	314	0.008±0.084	1	94.13	-
Unviable					
300	171	-0.001±0.092	4	88.61	89
200	67	-0.018±0.114	28	80.46	81
100	17	-0.046±0.154	97	57.92	64
50	0	-0.067±0.184	100	0	38

Given that the average density of mahogany gliders in their existing habitat is approximately 0.2 animals per hectare (0.24 hectares in continuous areas, 0.16 hectares in fragmented ones) (Jackson, 1999; Jackson, 2000c), the reserve size required for a stable and viable population of 800 individuals would be 4,000 hectares (Jackson, 1999). As gliders prefer specific tree species and associated forest types, only a proportion of a wooded landscape would be suitable for habitation (Goldingray and Possingham, 1995). Empirical observations indicate that the mahogany gliders may be using only about 50% of available habitat (Van Dyck, 1993; Eyre, 1993; Lyon, 1993; Jackson, 1999). This would raise the required minimum viable area to 8,000 hectares (Jackson, 1999). Alternatively, the minimum required area is sometimes calculated by multiplying the home range per pair by number of pairs (Goldingray and Possingham, 1995). Taking the largest estimated home range size so that habitat area is not understimated (23.15 hectares) and assuming all individuals are paired (hence 400 pairs), the minimum viable area would be 9260 hectares. Thus preservation of 8,000 to 10,000 hectares of required habitat containing about 800 adult gliders should achieve the minimum population viability target.

An Assessment of the Viability of Existing Habitat Areas on State Leasehold Lands in Hinchinbrook Shire

Fragmentation creates isolated pockets of populations within a sea of unsuitable habitat prone to extinction vortices (Gilpin and Soulé, 1986). Thus the most obvious corrective action is to maintain as large an intact habitat area as possible that span large portions of regional landscape (Noss and Cooperrider, 1994).

One of the largest remaining mahogany glider core habitat lies on state leasehold land near the town of Ingham in an area known as Wharps Holding (EPA, 2003c). It is a somewhat intact vegetation area surrounded by cultivated land, and is approximately 23,000 hectares in size and possibly contains the least disturbed of all coastal wetlands on the Herbert River delta (see area marked 'Area A' in Figure 8 below) (EPA, 2002b; EPA, 2002c; EPA, 2002d; EPA, 2003c).

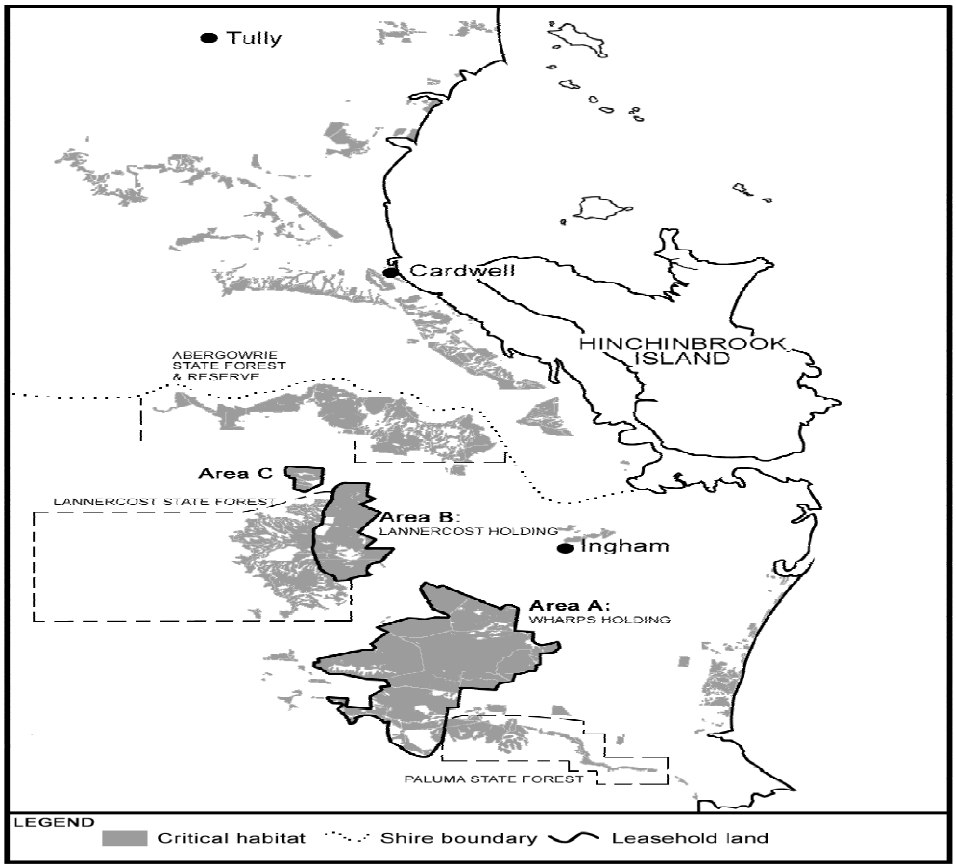

Figure 8: Land declared critical habitat of the Mahogany glider (EPA, 2002d) in Hinchinbrook Shire. Encircled grey areas are the Mahogany glider habitats on leasehold land assessed in this study. Most of the other habitat areas lie on state forest/reserve lands

It seems likely that a 10,000 hectare parcel of this land would contain sufficient habitat and a sufficient population of mahogany gliders to satisfy the minimum viable population target of 800 adult gliders, given the above analysis based on Jackson (1999) and on Goldingray and Possingham (1995)[2]. It will do this even if it contains only 0.1 mahogany gliders on average per hectare. If, however, the average density of mahogany gliders in Area A is only 0.05 per hectare, a 20,000-hectare parcel should be considered for protection to ensure a 95% probability of survival of mahogany gliders in this area for the next 100 years.

The probability of survival of the species could be further increased by establishing at least one other separate conserved area. It can be unwise to rely solely on a single habitat area in case an environmental catastrophe should occur. Therefore, many ecologists recommend maintaining several different protected areas for endangered species (Thomas et al., 1990; Murphy and Noon, 1992; Goldingray and Possingham, 1995). One possible second habitat area for conservation of the mahogany glider (separate from that in Area A) is in Lannercost the Holding area (QPRS, 2001).

In Lannercost Holding, there are two patches of state leasehold land towards the northwest of Area A (‘Area B’ and ‘Area C’ in Figure 8). The larger of these two is approximately 7500 hectares, the other about 625 hectares. While the former as such does not satisfy the required 8,000-9260 hectares for viability, linking it up to the latter through a habitat corridor (Wiens, 1996) and including habitat in the abutting Lannercost State Forest (approximately 5,000 hectares) easily brings total continuous size up more than 10,000 hectares. Building a corridor could prove expensive as these two leasehold areas are separated by a strip of freehold land by a distance of about 2 kilometres. However, it may still be worthwhile because mahogany gliders will travel along corridors of such length provided the corridors are of adequate width and suitable plant species composition (e.g. containing nectar- and pollen-yielding plants) (Jackson, 1999, p.61; Jackson, 2000d).

Nevertheless, even if a corridor is provided the area available of critical habitat in the Lannercost Holding area is less than in Area A. Incidentally, it might be noted that our estimate of suitable habitat area based on the most recent available map of land declared critical habitat to the mahogany glider (EPA, 2002d) is about 56,000 hectares (31,000 hectares on state leasehold land, 25,000 hectares on state reserved land). This is considerably

less than the general distribution area of 72,000 hectares suggested by Blackman et al. (1994) and Jackson (1998). It may indicate a diminution in the area of remaining habitat that is suitable for the mahogany glider. If Area A is set aside as protected area it will account for about two-thirds of suitable habitat on state leasehold land. It would make a significant contribution to the survival of the mahogany glider. However, detailed surveys should be undertaken in the particular area before deciding on the final conservation measures to adopt (Brito and Figueiredo, 2003). This does not mean that no prior conservation actions should be taken such as those involving temporary protection orders. The precautionary motive suggests that it would be wise to keep a wide range of options open by conserving initially a greater area of habitat than may be finally found necessary to ensure the survival of a minimum viable population of mahogany gliders in Area A, for example. This is rational in this case if one wants to maximize the expected value of decision-making about land use given that learning will occur (see for example, Tisdell, 1996, Ch. 5; Krutilla, 1967) or if risk-aversion is important.

Let us now consider the aggregate willingness to pay of the Australian public for measures to protect the mahogany glider and compare these with potential costs.

7. Benefit of Conserving Minimum Viable Suitable Habitat for the Mahogany Glider compared to Cost

There is no safe minimum population of a species that will ensure its survival for a specified period of time (Hohl and Tisdell, 1993)[3] but, as a rule, the larger the population of a species and its available habitat the higher is its probability of survival for a specified period of time. The above analysis indicated that a minimum population of 400 pairs of mahogany gliders and supporting habitat is needed to ensure a 95% probability of survival of a mahogany glider population for 100 years. Depending upon the quality of the habitat and average densities of mahogany gliders in it, a protected block of 10,000 hectares or 20,000 hectares in Area A shown in Figure 8 can achieve this objective.

How much might groups of Australians be prepared to pay to ensure protection of mahogany gliders in these blocks? Table 11 sets out the amounts that different groups of Australians might be prepared to pay for these conservation strategies assuming that the average

willingness to pay of $25 obtained in Survey I in the Brisbane sample applies. This is a conservative value compared with WTP results for Survey II and III.

Table 11:

Estimates of aggregate WTP for conservation of the mahogany glider if sample results are extrapolated to adult populations in Australia

Residential area	Population	Donation (AUD)
Brisbane	1,200,378	30,009,450
Queensland	2,847,249	71,181,225
Australia	15,083,863	377,096,575

Sources of population estimates: ABS, 2002; ABS, 2003a; ABS, 2003b.

As mentioned above, extrapolation from such a small sample to such a large population is problematic and probably the degree reliability of the estimate declines as the geographical range of the population increases. In addition to this the estimates are subject to many of the types of limitations that arise in contingent valuation analysis (see for example, Bateman et al., 2002). For example, in the survey no payment vehicle was stipulated. The payment is also a single bid one. This simplifies the questionnaire but may reduce accuracy. Bishop and Heberlein (1990), however, suggest that it may result in conservative estimates of WTP.

For the time being, let us however accept the figures in Table 11 as the best available ones. They imply that the adult populations of the various residential areas would be willing to pay on average the amounts per hectare shown in Table 12 to afford protection for a minimum viable population of mahogany gliders on 10,000 hectares of land or 20,000 hectares depending on what area is required.

Table 12:

Estimated (extrapolated) willingness to pay in AUD of groups of adult Australians per hectare for land areas to sustain a minimum viable population of mahogany gliders. Donations divided by sizes of population groups

Adult residents in the areas listed	Size of required area	
	10,000 hectares	20,000 hectares
Brisbane	3,001	1,501
Queensland	7,118	3,559
Australia	37,710	18,855

Note: Entries are rounded to the nearest dollar.
Source: Based on Table 11.

It is probably reasonable to assume that the willingness of Australians to pay for the conservation of the mahogany glider is somewhere between that estimated in Table 12 for Queensland and for Australia as a whole. Since the mahogany glider is confined to Queensland, possibly residents of other Australian states might be less inclined to pay for its conservation.

The question now needs to be considered of what would be the cost of protecting the mahogany glider on 10,000 hectares or 20,000 hectares of land in Area A. Two alternative strategies can be compared: (a) issue and enforce orders that no more removal of habitat of the mahogany glider on land in this area is permitted, and (b) terminate state land leases when they fall due, or maybe earlier with compensation, and put the land into a protected area, using (a) as an interim measure. Strategy (a) would probably be the least cost one but may not be the most effective for conserving the glider.

The economic cost of each strategy is equal to the difference between the discounted expected economic benefits now available to landholders and that available if either strategy (a) or (b) is adopted. Basically, strategy (b) will result in all future economic benefits from the land being lost by the landholder. In a perfect market situation, the market value of a property, if freehold, should represent its economic value. But the problem is that most of the land in Area A is state leasehold and is not marketable. The rent payable by leaseholders to the state is not public knowledge and private economic returns on these properties are not available. However, the unimproved land valuation for the purpose of paying local government rates may provide some indication of land values. We shall endeavour to gather information on these valuations, although they are liable to be an undervaluation because they do not include the value of improvements. Alternatively, if the sales values of a set of comparable freehold properties could be established, this would provide a basis for determining the private cost involved in resuming land to establish a protected area for the mahogany glider. We intend to investigate these values empirically in the future.

If the average loss in discounted economic value per hectare from protecting the mahogany glider on existing leasehold land in Area A is less than the WTP values in Table 12, the social economic benefit of protection of this area exceeds its cost. If aggregate WTP is as high as

the figure extrapolated for Australia, social net benefit from protection of this area is likely to exceed net benefits for its private use.

8. Further Observations and Discussion

The benefit of preserving habitat for the mahogany glider may be significantly greater than indicated above. This is because this habitat is likely to also conserve other valued wildlife species. Possibly an appropriate goal would not only be to conserve the mahogany glider but to sustain a whole ecosystem in which it is embedded. The mahogany glider, besides being highly endangered in itself, serves as a focal species with a spatial requirement large enough to take within its aegis other species and ecological processes integral to a functioning ecosystem (Wilcox, 1984; Soulé and Simberloff, 1986; Foose, 1993; Caro and O'Doherty, 1999). This approach to conservation may be more feasible economically. Because of its nocturnal and elusive nature, the glider, notwithstanding its existence value, may not have as high a use value to sightseers as other threatened (yet more conspicious species) that cohabit with it, such as the southern cassowary *Casuarius casuarius* or the Apollo jewel butterfly *Hypochrysops apollo apollo* (QPWS, 2001). Drawing visitors' attention to these other species benefits their cause and the glider's as well. In addition, information centres set up in these reserved areas could help heighten the public's awareness of the glider's full range of values (e.g. existence values, bequeath values, ecological values), and stimulate support for its conservation.

Active and appropriate management of conserved ecosystems may be required to sustain them. In an examination of 23 managed ecosystems, Holling (1995) found that it was poorly informed management activities that often lead to the collapse of the systems. Accordingly, understanding the components and dynamics of the ecosystem within which the mahogany glider lives is an important element in developing successful management practices. The species-diverse schlerophyllous woodlands upon which the mahogany glider is dependent are a case in point. These woodlands, once maintained as a consequence of traditional burning practices of Australian aborigines, may decline or disappear in the absence of such exogenous disturbances (Schaetzel et al., 1989). Succession from sclerophyll to rainforest as a result of the change in fire regime thus threatens the long-term survival of the mahogany glider (IUCN, 2002).

Because some active management of the habitat of the mahogany glider is needed, state regulations banning the clearing of habitat area are not in themselves adequate for the management of its population. For example, appropriate burning regimes must be established and surveillance maintained. In the absence of appropriate burning practices, some habitat of the mahogany glider could convert to rainforest that is unsuitable for the mahogany glider. It is likely to be easier to maintain appropriate management of the habitats of the glider in a national park. In our surveys, most participants favoured the creation of state protected areas to conserve the mahogany glider as well as regulations preventing the clearing of habitat of the mahogany glider on private land. Given the public's support for the creation of a protected area to conserve the mahogany glider, it is somewhat surprising that a national park has not been created for this purpose[4].

It is true that the creation of an appropriate national park in Area A would result in the State Government forgoing rental income for about 20,000 hectares of land, and loss of income to current leaseholders. However, indications are that this is a much smaller cost than the benefit to be derived from establishing a national park in this area. With appropriate planning and promotion, such a national park could provide a boost to tourism and income in the Ingham area.

Endnotes

[1] The legal conservation status of land containing habitat of the mahogany glider appears to be continually changing. *The Mahogany Glider Recovery Plan 2000-2004* of QWPS (2001) states that

"Approximately $11 million has recently been spent in the Hinchinbrook and Cardwell Shires on the acquisition of parcels of land which principally comprise mahogany glider habitat. Negotiations for acquisition of freehold and some leasehold lands containing habitat critical for the survival of the species are continuing. A number of properties have been declared nature refuges, or are proposed nature refuges, and are subject to Voluntary Conservation Agreements. Approximately 1120ha (around one percent) of mahogany glider habitat is protected within three nature refuges. Approximately 20 percent of remaining mahogany glider habitat is now protected within the Jourama Falls section of Paluma Range National Park, and Edmund Kennedy and Lumholtz National Parks. Clearing on leasehold land has

been severely restricted under local tree clearing regulations, a policy position reinforced in the draft Nature Conservation (Mahogany Glider) Conservation Plan 1999."

While this statement seems to provide a favourable view of conservation measures for the mahogany glider, the Queensland Environment Protection Agency in 2003 (see endnote 4) in its Draft Cardwell-Hinchinbrook Regional Coastal Management Plan expresses reservations about the degree of legal protection afforded to the mahogany glider. It seems that the *Vegetation Management Act 1999* of Queensland did not afford sufficient protection to the mahogany glider to ensure a high probability of its survival. This at least is a reasonable conjecture because the proposed Cardwell-Hinchinbrook Regional Coastal Management Plan would provide greater protection of critical habitats. However, a new legislation passed in Queensland, the *Vegetation (Application for Clearing) Act 2003,* means that effective from the 16th of May 2003, there will be an immediate halt on the assessment and approval of land clearing applications on freehold and leasehold land (OQPC, 2003; Corrs Chambers Westgarth, 2003). This moratorium is expected to remain in force at least until discussions are finalised between the Queensland and Federal Governments on a framework to govern vegetation clearing rates in Queensland and to protect native remnant vegetation (DEH, 2003). Although the moratorium applies to vegetation clearing applications from the aforementioned date onwards, it is likely that clearing applications submitted prior to that will still be processed and previously approved applications are unaffected.

[2] This should also be sufficient to take account of edge effects. Edge effects may need to be considered when determining the total habitat size to conserve. Boundaries of habitat islands are zones of influence where sunlight and wind from outside the boundary alter the microclimate at the edges, and where species not typical of uncleared habitat (such as adjacent pasture land floral species) may take root and compete with species native to the habitat area (Ranney et al., 1981; Murcia, 1995). Hence, the minimum viable habitat size may need to be equated to the size of the actual, undisturbed core habitat (total habitat area sans the edge area). For instance, if edge effects occurred up to 500 metres from the habitat boundary (as observed in one study of tropical forest fragmentation in Queensland) (Laurance, 1991), assuming circular habitat area shape then the total habitat size to conserve (one containing a core habitat area equivalent to the minimum viable habitat size of 8,000 hectares) would be 9680 hectares.

[3] Nevertheless, the concept of a safe minimum population of species introduced by Ciriacy-Wantrup (1968) persists in the economics literature and is used, for example, by Fredman (1995) in his analysis. It could, however, correspond to a population level of the species that results (in the presence of supporting habitat) a 'high' probability of the species' survival for a 'long' period of time. In effect such an approach is used here, but it is a subjective and lexicographic one.

[4] The Wharps Holding area, however, is part of the Halifax Bay key coastal site (as designated in the Cardwell-Hinchinbrook Regional Coastal Management Plan) (EPA, 2003c). This site extends from Forrest Beach to Crystal Creek. Key coastal sites are areas that contain coastal and other resources that require special coastal management (EPA, 2003c). This designation is an outcome of the *Coastal Protection and Management Act 1995*, the objective of which is, among others, to provide "protection, conservation, rehabilitation and management of the coast including its resources and biological diversity" (EPA, 2004). One of the coastal management issues identified for the Halifax Bay key coastal site is the protection of significant habitats for rare, threatened and significant species such as the estuarine crocodile, dugong and the mahogany glider. It has also been recognised that "core areas of mahogany glider habitat within Wharps Holding do not have a land tenure that reflects this area's important conservation significance" (EPA, 2003c). In view of this, the desired coastal outcome stipulated in the management plan is that high quality interconnected habitats are to be conserved to support viable populations of the mahogany glider and other species like the southern cassowary (EPA, 2003c). In fact, the promise of protection for coastal vegetation deemed ecologically significant has already elicited reactions from the agricultural sector. This is evident from the remonstrations of the Canegrowers Association of Tully district against classification as key coastal sites of certain freehold lands that were previously not protected under the *Vegetation Management Act 1999* (CANEGROWERS, 2003).

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