

Analysis of the costs and outcomes of attempts to relocate an urban flying-fox camp at Maclean, Australia.

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Abstract

Managing flying-fox camps has become an increasing challenge for the agencies responsible for managing both wildlife and residential communities along the east coast of Australia. Conflict arises between humans and flying-foxes either because flying-foxes locate their camp sites adjacent to, or within, urban areas or because people settle too close to existing camp sites. In many cases, members of the public have attempted to disperse or relocate such camps. This paper examines the consequences of a coordinated, government-sponsored attempt to relocate a flying-fox camp from the township of Maclean, northern NSW. This camp was a maternity site that had been occupied regularly by flying-foxes for over 100 years. Since 1999, government-controlled disturbances using continuous loud noise resulted in flying-foxes leaving the original camp site, and between 1999-2008 at least 12 temporary sites were subsequently used as camp sites by flying-foxes across the district (seven of these sites had not been previously occupied by flying-foxes). Flying-foxes made 23 attempts to return to the original camp site in these nine years although the number of attempts to return declined over time. In 2004, flying-foxes occupied a new camp site in the Iluka township, 16 km north east of the original Maclean site; this site was occupied continuously (although numbers fluctuated) in subsequent years. Residents of Iluka now wish to relocate this new

flying-fox colony. The total cost of the Maclean relocation to date (1999 – 2007) was estimated to be at least \$400,000 including 640 person-hours of effort. The experience at Maclean raises questions of how, and at what spatial scale, the success of relocation attempts should be determined.

Key words: *Pteropus*, fruit bat, relocation, wildlife management, human-animal conflict, urban economics.

Introduction

The intentional movement of animals or populations from one location to another has become a popular tool to manage wildlife, both for conservation and to resolve human-animal conflicts (Griffith *et al.* 1989; Wolf *et al.* 1996; Fischer and Lindenmayer 2000). In eastern Australia, the relocation of camps of flying-foxes (*Pteropus* spp.) is regularly proposed by some members of the community, typically in cases when these bats have established colonies close to residential areas or when human development occurs too close to established camp sites (Birt *et al.* 1998; Hall and Richards 2000).

The costs of relocating flying-fox camps can be considerable (West 2002; Thiriet 2005; Roberts 2006; Nelson 2008a) and there is ongoing debate around the long-term success of such projects (Hall 2002; Tidemann 2002; West 2002; Roberts 2006). However, very little effort has been allocated to monitoring the activities involved in previous relocation attempts, or their costs or outcomes, despite their long history in Australia (Hall 2002; Tidemann 2002; West 2002). This paper examines the consequences of attempts to relocate a flying-fox camp at Maclean in north east New South Wales (NSW), Australia. Based on the results, we discuss the utility of relocation as a management tool to resolve conflict between humans and flying-foxes.

Study region and its flying-foxes

Flying-fox camps in the Lower Clarence region

The Lower Clarence region in north-eastern NSW covers an area of approximately 1,500 km². The region has been extensively cleared for cane growing and cattle grazing, however, there are still areas of remnant native vegetation. By the end of the twentieth century the human population of the region was around 17,500, many of whom lived in coastal urban settlements along the Clarence River.

Flying-foxes were recorded in the region from at least 1885 (Tanton 1999; West 2002). The region is in the centre of the geographical range of the grey-headed flying-fox (*Pteropus poliocephalus*), suggesting longer-term occupation (i.e., much longer than historical records). The first quantitative records of the occupancy and abundance of camps commenced with a census of grey-headed flying-fox undertaken by the Australasian Bat Society in July 1998. Since 1998 there have been regular broad-scale systematic surveys of the usage of camps across the Clarence (Bennett unpublished data; Roberts unpublished data).

Until 1994, the grey-headed flying-fox was the main occupant of camps in the region, with sporadic influxes of the little red flying-fox (*P. scapulatus*) (Eby 2006). By 2007, both grey-headed and black (*P. alecto*) flying-foxes frequently occurred together in camps. According to historical records (Tanton 1999; West 2002), three camp sites have been habitually occupied over time: Maclean Rainforest Reserve which is described in detail below, Yaegl Nature Reserve (located 2.8 km north east of Maclean Rainforest Reserve) which is occupied during autumn and winter of most years, and Angourie Road (near Yamba) which is also occupied most years but not continuously (Figure 1). Flying-foxes have also been recorded using many other sites in the region as camps, but such sites appear to have been used temporarily or irregularly (Lunney and Moon 1997; Tanton 1999; B. Roberts pers. obs.). In the Lower Clarence only two sites have been occupied year round; Maclean Rainforest Reserve when

flying-foxes were not disturbed by the community and, since 2004, Iluka. These two year round camp sites are located in dense vegetation, mangroves and riparian rainforest, on the river (Tanton 1999; Roberts 2006).

Maclean Flying-fox Camp Relocation

For over 100 years, flying-foxes have regularly roosted in a rainforest area that is currently restricted to a small (one ha) patch of remnant forest - the Maclean Rainforest Reserve (MRR). This reserve is located on the southwest periphery of the Maclean township (29.4643°S, 153.2042°E; Figure 2). The number of flying-foxes using this site has fluctuated considerably over time, but has occasionally exceeded 100,000 individuals (Tanton 1999; West 2002). Historical records show that since the early 1890s flying-foxes using this camp have been repeatedly disturbed by humans, initially to control numbers, and later in attempts to relocate them, so as to reduce vegetation damage and impacts upon the neighbouring community (Lunney and Moon 1997; Tanton 1999; West 2002). There are numerous reports of private and government sponsored hunts to destroy or disperse the roosting animals using shooting, fires and explosives (West 2002). However, flying-foxes continued to return to this site despite these disturbances. In the early 1990's, as a result of the legal protection of flying-foxes, these disturbances ceased and animals continuously occupied MRR without further harassment until 1999.

Regardless of the presence of flying-foxes in MRR, the rainforest remnant and the surrounding land were set aside for public use by the Municipal Council of Maclean in 1889 (West 2002). As the Maclean township grew, several community facilities were constructed on the land including a cemetery, showground and, in the early 1960s, the local high school. The initial school buildings were positioned 80 m from MRR, but as the population of Maclean grew, additional classrooms and other education facilities were constructed closer to the reserve, including construction of classrooms within 10 m of the flying-fox camp in 1996

(West 2002). In 1994 and 1996 there were significant influxes of flying-foxes into the site (West 2002). This situation prompted increased pressure from the school community and nearby residents for the removal of the bats, due to concerns about the odour, noise, faeces and urine associated with the camp, and the perceived threat of disease transfer from the flying-foxes to the local residents (Tanton 1999). The roosting flying-foxes had also caused damage to parts of the canopy in the small patch of remnant rainforest. Others members of the community, including some residents, conservation groups, and welfare organisations, considered the site to be important for the local flying-fox population and argued that the historical camp should be protected. A variety of management options to reduce the conflict were discussed, including relocating either the school or the flying-fox colony. By 1998 the NSW government responded to the ongoing conflict by forming a working party to discuss and implement a draft action plan (West 2002). The working party consisted of representatives from local and state government (including the Department of Education and Training, the National Parks and Wildlife Service, and Department of Lands), the Maclean High School, and other sectors of the community (including the Maclean Parents and Citizens Association). The working party decided that the flying-fox colony should be subjected to a controlled disturbance regime with the aims of reducing numbers at MRR and surrounds and enticing the bats to move to a nearby camp site (Yaegl Nature Reserve). Evidence of repeated but irregular use by flying-foxes (generally between February - June) had been recorded at this site. The species that frequented the site was generally unknown because of the reserves' inaccessibility but recent observations of this camp suggests it is primarily used by little red flying-foxes, although black and grey-headed flying-foxes are also known to have used the site.

The relocation efforts broadly followed advice from a bat expert (relocation proposal by Dr C. Tidemann included in Tanton 1999). However, this was a controversial decision, and other flying-fox ecologists questioned whether it would be an effective long-term solution (West 2002). The relocation activities, using loud noise, commenced in 1999.

Methods

Response of Maclean flying-foxes to relocation: survey methods

Data on flying-fox occupancy and abundance within camps across the Lower Clarence region over the period of April 1999 - October 2007 were compiled from a survey of the literature (Tanton 1999; Tidemann 2002; West 2002; Tidemann 2003; Roberts 2006). Information relevant to the relocation of flying-foxes from MRR was obtained from the three involved stakeholders (the NSW Departments of Environment and Climate Change, and Education and Training, and the Clarence Valley Council) through applications made under the NSW Freedom of Information Act 1982.

Additional information on the location of historically- and currently-used camps in the Lower Clarence region, patterns of occupancy and abundance, and details of the attempts to relocate flying-foxes from MRR, was obtained from the field notes of biologists and naturalists (P. Eby, B. Roberts, M. Williams, J. Kennedy); the records of interested, long-term residents (G. Bennett, C. West, P. Wrightson); and from council staff (B. Sansom, N. Greenup and M. Forester Clarence Valley Council) and persons living near MRR (J. Storock, J. Clowes, H. Naylor).

Determining financial costs and disturbance effort

Costs associated with the relocation attempts were obtained from involved stakeholders (the NSW Departments of Environment and Climate Change, and Education and Training, and the Clarence Valley Council) through applications made under the NSW Freedom of Information Act 1982 (FOI). Costs were allocated to one of several categories including consultant fees and wages, plans of management, logistics of the dispersal, research and acquisition of alternative habitat. Actual costs associated with some aspects of the disturbance were difficult to obtain and it is likely that some components have not been included in the total cost. The disturbance effort (person-hours) required to disperse flying-foxes from Maclean was

summarised from information obtained under FOI, conversations with council staff (N. Greenup and M. Forester Clarence Valley Council), author's personal observations and published articles (Tideman 2002, 2003). Effort was calculated on a monthly basis, using the number of days on which dispersal efforts were known to occur, multiplied by the number of people required and the total disturbance time per day.

Results

Disturbance method

The standard method used to disturb flying-foxes at MRR consisted of 3 or 4 people working around the camp's perimeter to generate loud, continuous noise. At the time of the initial relocation in April 1999, noise was generated for 30 minutes at dawn and dusk (Tidemann 2002, 2003). Subsequent disturbances lasted for up to 2 hours per day (typically split into two periods: morning before 9 am and afternoon after 2 pm). The noise was generated using stock-whips, metal drums, gongs, starting pistols, firecrackers, whistles and small-unmuffled two-stroke motors such as chain saw and lawn mower engines. These disturbances were observed to cause an immediate response from the flying-foxes, with the majority of the animals taking to the sky, vocalising and circling around the camp site for prolonged periods of time, ranging from 2 – 20 minutes (Figure 3). Typically, all flying-foxes left the MRR after 2 - 14 days of disturbance activity. The human effort required to relocate the animals appeared to be positively related to the number of flying-foxes in the camp, and the length of time that flying-foxes had been allowed to persist at the site prior to being disturbed. For example, if the number of flying-foxes in the camp was greater than 1000, more hours of disturbance-effort were required to induce their departure. Further, if flying-foxes were allowed to persist at MRR for more than one week a greater number of days of disturbance activity was required.

Disturbance of flying-foxes at the Maclean camp

Between April 1999 and October 2007, there were 23 separate documented attempts by flying-foxes to re-establish a camp at MRR (Figure 4). For the 12 months after the first disturbance, there were monthly re-occupation attempts by flying-foxes. From 2000 to 2007 attempts by flying-foxes to re-establish the camp commonly occurred in September/October, during the start of the birthing season. In general, when flying-foxes attempted to return to MRR their numbers built up to 1,000 - 2,000 individuals over a few days. If further disturbances did not commence immediately, their numbers typically continued to increase rapidly.

After each disturbance, flying-foxes roosted in scattered groups in trees within the high school grounds and the immediate surrounds, and made regular attempts to return to MRR either overnight or once the noise had abated. In most cases, a large proportion of the colony moved 350 m northeast from MRR into vegetation around a nearby electricity substation, and residents' backyards (Maclean gully, MG) (B. Roberts pers. obs.; West 2002; Tidemann 2003). Flying-foxes typically remained in this area for several months, although residents often harassed the animals in an attempt to induce them to move on (B. Roberts pers. obs.).

There were no observations of flying-foxes moving from the MRR to the proposed replacement camp site at Yaegl Nature Reserve nor was there any evidence of an immediate increase in the population of Yaegl at the time of any of the relocations.

After 1999 the number of attempts by flying-foxes to re-establish a colony at the MRR progressively declined, but flying-foxes still returned to the site nine years after the initial relocation. In October 2007, 2000 flying-foxes roosted in the MRR and a disturbance was conducted over 5 days (B. Roberts unpublished data). By the time disturbance actions in the MRR ceased, approximately 1,000 flying-foxes were roosting in residents' backyards at MG.

Animals (typically between 5000-7000) remained in this location until June 2008 despite frequent attempts by local residents to move them from the site.

Cost of the relocation

Relocation attempts cost at least \$400,000 between April 1999 and December 2006, including over 640 person-hours of effort (Table 1; Figure 4). The actual total cost of relocations was difficult to obtain due to poor records, the time that had elapsed since the initial relocation, and the difficulty of estimating the cost of participation from government representatives. Other costs that have not been included in Table 1, but that would have significantly contributed to the total include: the costs of attendance (time, travel and accommodation) for government representatives at several years of community meetings; wages and administration costs for the various government bodies involved in regulating the relocation; the cost of vaccinating (against Lyssavirus) carers, veterinarians and government staff who monitored the welfare of the animals during the disturbance (a regulatory condition for the relocation attempt); and legal costs incurred when a conservation group (North Coast Environment Council) took the licence holder (Department of Education and Training) to court to prevent disturbances during the maternity season. Works also took place to reduce the flying-fox impact on Maclean High School (including covered walkways, air-conditioning and double glazing windows). The cost of these was \$360,000, although this is not a cost of the relocation but rather one of impact mitigation.

Assessment of flying-fox camp sites used since the relocation

After the initial disturbance of the Maclean flying-fox camp in 1999, at least 12 sites were used as campsites by flying-foxes across the Lower Clarence region (Figure 1). Five had been used as camps prior to the 1999 disturbance (Ulgundahi Is., Angourie, Yaegl Nature Reserve, Ashby and Lawrence) and seven appear to be new sites that were only been used after the disturbance (Maclean gully, Whyna Is., Sleeper Is., Thorny Is., Bolorobo Is., Iluka, Warregah

Is.). Six of these new camp sites (all except the Maclean gully) are situated in small mangrove patches or islands in which tree cover has only recently (last 15 years) developed to the extent where it provides sufficient roost habitat for the establishment of a flying-fox camp. All except one of the 12 sites were temporary camps used by flying-foxes for weeks or months and then abandoned. However, in 2004, a new camp was established within the Iluka township, 16 km from MRR, and this site has since been continuously occupied by flying-foxes. Use of temporary camps in the Lower Clarence largely ceased after the establishment of the Iluka camp. Due to the proximity of the site to residential areas, some residents of Iluka now wish to relocate this flying-fox colony (Roberts 2006).

Discussion

Effect of disturbances on site use by flying-foxes

Has the relocation of the Maclean flying-fox camp been successful? The Maclean example is often termed a success by the principle investigator (Tidemann 2003), other researchers and residents to argue for relocating camps elsewhere (Nelson 2008a, b). Perhaps from the narrow perspective that flying-foxes have failed to maintain a continuous presence in MRR since 1999 it could be viewed as successful. However, flying-foxes are still roosting in the vicinity of Maclean, they continue to attempt to resume occupation of their historically-used camp site often prompting conflict with local residents, and following the implementation of the disturbance program they have set up a previously-unknown camp in a nearby urban setting at Iluka. That is, the relocation is unlikely to be considered a success by the broader community or government authorities charged with managing the conflict, who now have to deal with a new set of complaints from Iluka and Maclean residents, while managing the continued attempts by flying-foxes to resume their original Maclean camp. Seen in this light, the Maclean disturbance program, rather than resolving the problem, appears to have merely succeeded in moving the problem elsewhere at considerable and ongoing cost to the local community.

Attempts to relocate flying-foxes using coordinated noise have also occurred at other locations in Australia (Melbourne Botanical Gardens, Victoria; Singleton and Sydney Royal Botanic Gardens, NSW; Boyne Island, Charters Towers and Townsville, Queensland; Batchelor and Mataranka, Northern Territory). Some of these attempts have resulted in flying-foxes moving from the roost (Tidemann 2003; Phillips *et al.* 2007; Nelson 2008b), however in most cases the effect is temporary, and ongoing programs of dispersal are required because flying-foxes make regular attempts to return to their original site (West 2002; Roberts 2006; Phillips *et al.* 2007). In other relocation attempts, the flying-foxes have not dispersed at all (Vardon *et al.* 1997; Richards 2002; Roberts 2006). The relocation of the Boyne Island flying-fox camp (Gladstone, Qld) saw an increase in flying-fox abundance at other existing camps, the formation of several new camps a short distance from the original camp site, and the regular return of flying-foxes to the original site despite repeated disturbances (Roberts 2006). Human and flying-fox conflict continues to be an issue in this area. The dispersal of the camp in the Melbourne Botanical Gardens eventually resulted in flying-foxes establishing two new camps in unexpected locations, rather than in the target site identified in the relocation plan (Department of Sustainability and Environment 2005; Roberts 2006). Flying-foxes returned almost monthly during the first year of disturbances at Melbourne, however since 2004 flying-foxes have only attempted to return to the gardens on one occasion (R. van der Ree pers. comm. 2008, University of Melbourne). There have also been three separate attempts by the Singleton City Council to move roosting flying-foxes from one of the town's public parks using spotlights and reflective material, water from fire hoses and sprinkler systems, and loud noise (e.g., modified mowers and bird-frite) with no success.

At present, knowledge of the movement patterns of flying-foxes and the factors influencing the establishment and persistence of camps is insufficient to predict where flying-foxes will move once relocated from a particular camp. Prior to disturbances at MRR, it was suggested that flying-foxes could be shifted to Yaegl Nature Reserve, a nearby camp site which had

been historically used by flying-foxes (Tanton 1999; Tidemann 2002, 2003). However, differences in the patterns of use of the Yaegl camp relative to the MRR indicate that it has not formed a replacement site. While flying-foxes have been recorded in Yaegl Nature Reserve since 1999, the site has not been continuously occupied by grey-headed or black flying-foxes (the main occupants of MRR). Instead it has been primarily used for short periods of time during the autumn and winter months by nomadic groups of little red flying-foxes (G. Bennett unpublished data; B. Roberts unpublished data).

Relocations also have the potential to shift flying-fox camps to nearby, possibly more controversial sites. In eastern Australia, flying-fox camps occur in a variety of habitats from continuous forest to small remnant forest patches (Eby 2002; Roberts 2005), but there is emerging evidence that there is a tendency for camps to be situated in urban environments (Birt *et al.* 1998; Hall 2002; Roberts 2005). Therefore, further relocation attempts in Maclean or Iluka may result in a shift to other urban areas in the region.

Cost-effectiveness of relocation attempts

Additional factors that require consideration when assessing the success of a relocation attempt include the costs of dispersal, which are influenced by the period of time over which disturbances are required. Costs are relevant because in most situations there may be a range of alternative management actions to reduce conflict other than dispersal, such as subsidising double glazing of windows and the air-conditioning of rooms to reduce impacts of noise and smell (see Roberts 2006). In some situations it may be possible to manage camp vegetation to encourage flying-foxes to roost further from areas of human activity (Coffs Harbour City Council 2005). From a cost-effectiveness perspective, these options may be more suitable to the Maclean situation than dispersal. The duration of a relocation attempt bears on the length of time that stakeholders (e.g., the broader community) are prepared to support a program, which on the basis of the Maclean example may need to continue for many years. The issues

of alternative approaches to the problem, their costs, and their social acceptability can be very complex. However to date neither the alternatives nor the long-term activities required for relocation have been fully costed when considering the success of the Maclean relocation.

The costs of flying-fox dispersal and relocation may be considerable. For example, the cost of relocating flying-foxes from Maclean was at least \$400,000 and is ongoing; the true figure is probably larger, but difficult to document due to poor reporting practices (Roberts 2006). In Melbourne, thousands of person hours of effort and a substantial amount of money (approximately \$3 million) were spent on the process of relocating flying-foxes from the Royal Botanical Gardens (Roberts 2006) (refer to Table 1). To date Singleton City Council has spent approximately \$87,000 on attempts to relocate flying-fox from Burdekin Park (Roberts 2006; A. Fletcher pers. comm. 2006, Singleton City Council). In March 2008, it was estimated that another \$300,000 of financial commitment over a three-year period would be required for future attempts to shift the animals (S. Neal pers. comm. 2008, Singleton City Council).

Managing flying-fox relocations in the future

Relocation continues to be seen as a solution to problems with flying-fox camps in urban areas. Since 2006, proposals were made to either State and/ or Commonwealth government to relocate flying-fox camps in Sydney, Murwillumbah (Dallis Park), Lismore, Singleton, Batchelor, Charters Towers and Townsville. However, it is important to determine the magnitude of the perceived problem before exploring potential management options, including relocation. For example, if noise, smell and faeces from the camp were only affecting a small number of residents, then management options may only warrant targeted action at a local scale. In such cases, it may be possible to reduce impacts on affected residents through actions other than dispersing the flying-foxes (e.g., creating buffers between

houses and roosting flying-foxes and constructing sound barriers; see Roberts 2006 for review of further management options and their estimated costs).

There is also a need to educate the public to reduce antipathy towards flying-foxes. For example, managers of urban camps at Bellingen, Coffs Harbour, Wingham Brush and Kuring-gai (Gordon) in NSW, and Woodend in Ipswich, Queensland, have attempted to alleviate the concerns of nearby residents through strategies such as community camp revegetation programs coupled with minor habitat modification around the camp's periphery, education days, and the promotion of tourism to camp sites (Pallin 2000; Smith 2002; Coffs Harbour City Council 2005; Hall 2006). Similar approaches have been used to successfully manage residents' concerns about six flying-fox camps in suburban Brisbane, Queensland, that potentially could have been sources of major conflict (Hall 2002, 2006).

Many of the conflicts between humans and flying-fox camps may be attributed to poor planning and inappropriate development near established camp sites (West 2002; Smith 2002; Eby 2002). Creating public open space buffers around established camp sites, aligned with more sympathetic developments, could minimise future conflict, particularly in new residential areas. This is mainly an issue for local government, although there may also be a role for State and/ or Commonwealth planning policies to guide development of areas adjoining flying-fox habitat, given that some flying-foxes species are classified as 'vulnerable to extinction' under some State and Commonwealth legislation.

In cases where relocation is considered a preferred management option, the objectives of relocation and what might constitute 'success' need to be clearly defined. In particular, the extent of responsibility of the licensee to the broader community (i.e., ensuring that any replacement camp is not a source of conflict) should be explicitly identified. The length of commitment to relocation also needs to be more clearly understood by proponents, given that flying-foxes show high fidelity to traditionally-used camp sites (Ratcliffe 1931; Nelson 1965;

Eby 1995; Richards 1995; Tidemann 1999; Tidemann *et al.* 1999). The continued attempts by flying-foxes to re-establish the Maclean camp may be related to the role of the site as a maternity camp. As flying-foxes can live for approximately 15 years in the wild (Martin and McIlwee 2002; Divljan *et al.* 2006), attempts to re-establish the MRR camp may continue for another few years (if sites are occupied on the basis of individual memory), or indefinitely (if sites are occupied on the basis of habitat attributes or cultural transmission). Such factors need to be considered and addressed in decisions to disperse or relocate flying-fox camps.

Future relocation attempts also need to be accompanied by an adequate monitoring program, to record the actions taken and their costs, and also to determine the short- and long-term outcomes of the disturbance. Monitoring of the outcomes could include both tracking the individual movements (for example, with satellite- or radio-telemetry) over the first 12 months, and regularly monitoring of both the original site (i.e., species present, their abundance, breeding status) and other sites in the region. Without such monitoring, there is a significant risk that attempts at relocation will continue to be represented by proponents as 'successful', when in fact they have simply shifted the problem (to other places or to the future), rather than solved it.

Conclusion

The resolution of conflicts between humans and flying-foxes is important to the conservation and management of flying-foxes in Australia. Camp relocations are currently commonly proposed as a management tool to reduce conflicts between humans and flying-foxes. However, relocations are often carried out in an ad hoc fashion and are not carefully documented, costed or monitored. Further, most relocations have had limited success in moving the flying-foxes to new sites, in some cases these new sites have been in unanticipated and undesirable locations, and relocation attempts may be costly. The location of flying-fox camps in urban areas is likely to continue to be an issue in the future. A better

understanding of flying-fox relocations will significantly assist organisations responsible for managing flying-fox camps and help identify long-term management solutions that are acceptable to the entire community.

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Figure 1: Map of the Lower Clarence region with all known flying-fox camps* occupied since the Maclean disturbance in April 1999. Yellow circles = historical sites used prior to the disturbances, Triangles = sites that have been occupied since the disturbance (red triangles continuously occupied sites and blue triangles were temporary sites generally on mangrove islands).



* Lower Clarence flying-fox camps: LA = Lawrence; MA = Maclean; MG = Maclean gully; AS = Ashby; YG = Yaegl Nature Reserve; YA = Yamba; UL = Ulgundahi Island; WH = Whyna island; TH = Thorny Island; SL = Sleeper Island; IL = Iluka; BO = Bolorobo Island; and WA = Warregah Island.

Figure 2: The Maclean Rainforest Reserve (1 ha of lowland subtropical rainforest - MRR) and surrounds, including: the Maclean gully (circled - MG), Maclean High School and TAFE (large buildings to the centre left with the dates of construction), sports oval (circular clearing in centre), school agriculture plot (clearing below MRR) and the Clarence River (left of MRR). Arrows represent residents that are affected by flying-foxes when they roost in the Maclean gully.



Figure 3 Picture of the effects of disturbance on flying-foxes in the Maclean Rainforest Reserve (1994). Photo copyright of Department of Environment and Climate Change (NSW).



Table 1 Estimated costs of the relocation of flying-foxes from the Maclean Rainforest Reserve and the Melbourne Royal Botanical Gardens. Several additional components of the Maclean costs are not included due to lack of records (see text). Cost for the Melbourne Royal Botanical Gardens derived from S. Toop (pers. comm. 2006, Department of Sustainability and Environment) and Department of Sustainability and Environment (2005).

Category	Description	Maclean Rainforest Reserve	Melbourne Royal Botanical Gardens
Consultant fees and wages	Wages for main investigator, assistants and government staff that assisted with the dispersal	\$51,000	Between \$100,000 and \$200,000
Plans of Management	e.g., Maclean, Tanton (1999) and Melbourne, Department of Sustainability and Environment (2005)	\$20,000	\$1,700,000
Logistics of the Dispersal	Equipment hire or purchase, materials, vehicles, contract labour	\$25,000	\$250,000
Research projects		nil	\$300,000
Alternative habitat	Cost to purchase alternative habitat (Yaegl Nature Reserve ¹) and/ or enhance alternative habitat	\$300,000	\$600,000
		\$396,000	Between \$2,950,000 - \$3,050,000

¹ The Yaegl Nature Reserve was purchased by NPWS in 2001 (with Commonwealth Government assistance) because of reports of increasing use by flying-foxes; and, due to the ecological significance of the dominant *Melaleuca* swamp forest (a threatened ecological community).

Figure 4 Documented disturbance effort (person-hours) required to disperse flying-foxes from the Maclean Rainforest Reserve since the initial major relocation effort in 1999. Note that the data do not include any unauthorised disturbances conducted by residents of Maclean. Data from Tidemann (2003), Clarence Valley Council, and authors.

