A REVIEW OF RELATED STUDIES

Most related studies involving the measurement of aircraft noise and activity in relation to human recreational use in National Parks have been undertaken in the United States of America. Related studies undertaken to date in Australia have been primarily social surveys or have addressed the impacts of noise on other species.

Studies Undertaken in Australia

Brown (1986) undertook a study to determine how seaplanes affect people's perceptions of their experience on Green Island, GBRMP. Brown (1986) found that for 95% of visitors, seaplanes were an acceptable part of their experience. For the 5% who found that seaplanes decreased their enjoyment of the island, the main reasons were noise and beach conflicts. The proportion of people who found that seaplanes decreased their enjoyment increased with an increase in the frequency of seaplane operations. Brown (1986) also took spot sound level measurements at various points around Green Island to determine daytime background sound levels and seaplane sound levels. Brown (1986) used the metrics 'Lmax' and 'duration above background' as means of assessing the intrusiveness of seaplane noise. For background sound levels as a result of waves, wind and people, peaks recorded ranged from 40dBA - 54dBA. Peak sound levels made by seaplanes always occurred during takeoff and were recorded in the range of 58dBA - 76dBA. During takeoff seaplane sound levels were concluded to generally be 10 - 20 dBA above background sound levels for a duration of 25 seconds.

Dellora et al. (1984) investigated conflict between types of recreationists (bushwalkers, picnickers and recreational vehicle users) in Victoria, Australia, and found trail bike noise to be the primary cause of concern. Beal (1994) reports on a study done in Queensland on camper's attitudes to noise and regulations in National Parks. The study did not specifically address the issue of aircraft noise. However, it did find that campers were most intolerant of technology related noise, specifically car, radio and television noise.

Mathers (1987) did an honours dissertation from Griffith University on the effect of aircraft noise on the behaviour of *Sterna bergii* (Crested Turns) on islands in the GBRMP and concluded that aircraft noise had a significant effect on their behaviour. Hicks et al. (1987) investigated seaplane and vessel disturbance of nesting seabird colonies on Michaelmas Cay. They concluded that seaplane operations had a significantly greater likelihood of resulting in seabird disturbance than vessel operations.

Ormsby and Shafer (1999) undertook a social survey of visitors to Whitehaven Bay, Whitsunday Island. They aimed to assess visitor use and experience of the area, while evaluating the influence of aircraft and watercraft on visitors' use and perceived amenity of the beach. Data was collected during 16 survey trips carried out between mid-March 1999 and mid-April 1999. Survey trips were undertaken aboard tour craft visiting Whitehaven Beach as part of their regular operation. Respondents surveyed spent an average of 2 hours on Whitehaven Beach. Ormsby and Shafer (1999) concluded that only approximately 10% of people were adversely affected by aircraft, watercraft or crowding on Whitehaven Beach and that the natural and scenic qualities of Whitehaven Beach were attributes that visitors received the most enjoyment from.

They observed ROS Setting 2 to be the most frequently visited setting by people and watercraft. They recorded an average of 137 people, 2 large vessels, 3 medium boats, 2 small boats and 4 yachts in setting 2 during their survey trips. An average of 1.3 seaplane overflights and 1.0 helicopter overflight were observed during their survey trips and no difference in the perception of aircraft activity was found between the settings visited. However, limitations experienced during data collection are expected to have affected results. Ormsby and Shafer's (1999) data was collected during a low season of use at Whitehaven Beach while weather conditions were unfavourable. Only 12% of the visitors sampled experienced fine weather. Furthermore, an equal cross representation of respondents from small and large tour vessels visiting a range of ROS settings was not obtained. 86% of respondents visited Setting 2 (high use setting), 11% visited Setting 3 (moderate use setting) and 3% visited Setting 5 (protected setting) while 73% of visitors surveyed traveled aboard the largest watercraft which has a capacity to carry up to 400 passengers. Thus, the majority of respondents were traveling in large groups to areas designated for more intense use.

Studies Undertaken Overseas

The United States has been active in addressing the issue of aircraft noise in its National Parks where an estimated 30 percent of all non-Alaskan National Parks experience overflight problems (US National Park Service 1994). Issues of aircraft noise in United States National Parks and at the Grand Canyon particularly, ultimately led to the enactment of the *US National Parks Overflights Act of 1987*. Aside from stipulating specific regulations for aircraft overflying certain US National Parks, the Act also stipulated that impact assessments and monitoring studies of aircraft flights over US National Forests and Parks be undertaken (US Forest Service 1992; US Federal Register Dec. 1996).

A recent development in the US, as a result of studies undertaken in accordance with the *Overflights Act 1987*, and scheduled to come into effect in early 1998, involves changes in the Federal Aviation Administration (FAA) legislation governing overflights over the Grand Canyon National Park. Changes include the capping of flight numbers, the further use of curfews and the modification of flight corridors (US Federal Register Dec. 1996; McCain 1997). FAA regulations also recently banned tour overflights in Rocky Mountain National Park where air tour operators were not yet in operation (US Federal Register May 1996). This is viewed as a proactive measure to prevent environmental problems before economic loss to air tour operators becomes an issue (Ernenwein et al. 1996).

Methods Used to Assess and Monitor Overflights

Several types of studies have been used to assess both actual and human perceived impacts of overflights and to monitor the effectiveness of legislation regulating overflights in US National Parks and Forests.

Studies have been based on assessing either spatial or temporal differences in aircraft sound exposure levels. Bowlby et al. (1986; 1990) undertook a spatial study in Grand Teton National Park, Wyoming, USA, aimed at determining whether or not a 55dBA Ldn contour, which had been generated in the vicinity of Jackson Hole airport, actually extended beyond the set boundary and into a defined noise sensitive area where the Ldn limit had been set at 45dBA. They monitored four sites (three of which were in the 45dBA area and one of which was in the 55dBA area) using automated type 1 sound

meters, over four week long periods. They found that standards were generally complied with but that newer (B737/300) aircraft were less likely to exceed the standards than older and noisier (B737/200) aircraft. This highlights the importance of using quieter aircraft technology. Two monitoring studies based on assessing primarily temporal changes are discussed by the US National Parks Service (1994). Both studies aimed to determine whether or not legislative changes issued by the FAA in May 1988 and governing overflights over the Grand Canyon had been effective. Thus, comparative measurements based on the metrics Lmax and 'Percent of time audible' were taken prior to and after the legislative changes had been enacted (Fidell et al. 1994; US National Parks Service 1994).

Baseline and monitoring studies undertaken to date can be further summarised in the following categories:

- Indigenous and self noise sound studies;
- Aircraft sound studies;
- The combined use of secondary data sources with limited primary data to predict wide ranging impacts;
- The development of dose-response relationships and curves.

Indigenous and Self Noise Sound Studies.

A number of studies have been undertaken to establish and characterise indigenous sound levels in protected areas both for their own sake and to allow the impact of aircraft to be assessed.

Overall, indigenous sound levels were calculated to range for varying ecotypes from about 10dBA - 55dBA with the lowest measurements generally occurring during the night. Ambient indigenous sound levels in the order of 65dBA are postulated to be commonplace on windy days or near waterfalls or surf. Self-noise levels of hikers and horseback riders were shown to be more variable and an average of 13dBA higher than indigenous sounds. In order to calculate indigenous sound levels, artefacts of measurement including wind noise, and high level noise intrusions such as, animal noise, thunder and aircraft overflights were removed from the estimations (Fidell et al. 1990; Bowlby et al. 1990; US Forest Service 1992).

High spatial, temporal and spectral distributions of both indigenous and ambient sound levels were found to occur (Fidell et al. 1990; Bowlby et al. 1990; US Forest Service 1992). Indigenous sound levels were also found to have predictable statistical properties including a strong relationship between A-weighted sound levels and wind velocity. Furthermore, spatial, temporal and spectral patterns of correlation of sound levels can be used to quantify the degree to which anthropogenic noises intrude upon indigenous sound levels (Sneddon et al. 1994).

Aircraft Sound Studies

Aircraft sound studies have aimed to determine the acoustic profiles of both protected areas experiencing overflights and of various types of aircraft. Peak aircraft decibel levels recorded for all studies ranged from 47 to 107dBA. The majority of peaks being in the mid to lower section of this range. For example, Tabachnick et al. (1994) collected about 2 hours of overflight sound data in each of twelve wildernesses, and found that seven of ten sites recorded maximum peaks of 70dBA and below with estimated average peak levels ranging from 53dBA - 66dBA. Bowlby et al. (1990)

undertook a more extensive study over four week long periods. The data they recorded included aircraft takeoffs and landings. For one season at one site, they found that general aviation aircraft had a mean sound exposure level of 75dBA. Fidell et al. (1992) studied overflights in three wildernesses. Maximum aircraft noise levels recorded were in excess of 100dBA with an onset rate of 70dBA/s. Low flying military jets and helicopters were found to cause the highest sound levels typically reaching peaks of 70 or 75dBA with durations above background being longer for helicopters (approximately 100 seconds). Propeller driven planes typically reached amplitudes of about 62dBA with durations above background levels in the range of 60 seconds. High altitude transport jets typically reached an amplitude of about 58dBA for durations above background sound levels of about 40 - 60 seconds. Some high altitude overflights had virtually no measurable impact.

Horonjeff et al. (1993) determined the acoustic profiles for sites in the Grand Canyon, Hawaii Volcanoes and Haleakala National Parks. At the Grand Canyon data was collected at 23 sites (for an average of either 4 or 15 hours) in both flight and flight-free (below 14,000 ft) zones. Based on the metric 'percent of time audible', the general range of aircraft sound exposure in the Grand Canyon National Park was found to be from 5 - 80 percent of the time.

One method of ascertaining the impact of aircraft on indigenous sound levels is by comparing 'total' (all sources) Ldn with either 'aircraft only' or 'indigenous only' Ldn. If the difference between 'total' and 'aircraft only' Ldn is small (less than 3dB), aircraft are concluded to have been the dominate sound source. However if the difference is large (10dB or greater), aircraft are concluded to have had negligible effect on the total Ldn (Bowlby et al. 1990). Conversely the reverse is true if the comparison is between 'total' and 'indigenous only' Ldn (US Forest Service 1992). 'Total' Ldn can be relatively easily measured using an automated sound meter to record Leq values over a chosen period, such as 1 hour, which can then be computed into day (07:00 - 20:00), night (20:00 - 07:00) and 'total' Ldn values (Bowlby et al. 1990; US Forest Service 1992). 'Indigenous only' Ldn can be computed from short term Leq measurements (US Forest Service 1992). 'Aircraft only' Ldn values can be established by non-automated short term Leq recordings (US Forest Service 1992) or automated recordings (Bowlby et al. 1990). Bowlby et al. (1990) made automated 'aircraft only' Ldn measurements using a sound level threshold trigger to initiate recording. When compared with logs of aircraft activity, non-aircraft events (such as animal activity) were factored out of the 'aircraft only' Ldn calculation.

Sound level recordings have been related to aircraft types and movements (e.g. flight paths and directions of takeoff) allowing determination of the best types of movement and aircraft for preserving the natural quiet (Bowlby et al. 1986; Bowlby et al. 1990).

The Use of Secondary Data Sources

Secondary data sources have been used in conjunction with primary data to allow predictive modelling of the extent and impacts of aircraft overflights in protected areas. Tabachnick et al. (1992) developed a database (based on types and numbers of overflights), on behalf of the US Forest and National Parks Services, which was used to estimate overflight exposure for wildernesses where direct sound measurements weren't made. Noise exposure prediction equations and sound recordings made in similar wildernesses to those in question were used to compute the estimates. The

database was then used to select sites with a range of visitor use and aircraft exposure conditions for social impact assessment. However, accurate determinations of aircraft activity and sound impacts over National Parks and Forest Service Wildernesses based on secondary data was concluded to be extremely difficult to achieve (US National Parks Service 1994).

The US National Parks Service (1994) also discuss an overflight decision support system (NODSS) which was developed to allow computerised acoustic modelling of sound levels over large areas. In the case of the Grand Canyon, NODSS was used to model future projections of the restoration of natural quiet under different management strategies. Information about types, numbers and altitude of aircraft, their flight routes and the topography of the region in question is used to compute sound levels over parks. Several sound metrics are able to be calculated including the time period that aircraft sound levels are above a specified threshold, Lmax and Leq values.

Dose-Response Relationships

Dose-response relationships describe the association between dose (aircraft exposure) and response (visitor impact). Once defined they can be used to produce dose-response curves, which can then be used to predict response by measuring or predicting dose (US National Parks Service 1994).

Dose response curves have been developed for several National Parks using the metrics: Ldn; Lmax; visit duration; visitor self reports of the numbers of aircraft noticed; Leq; and percent of time audible. Metrics were measured in conjunction with on site interviews at sites of varying levels and types of overflight exposure, visitor density and ecotypes. The metric found to be the best correlated with visitor response to aircraft sound was 'percent of time audible'. However, for predictive purposes, Leq is considered valuable, particularly if used in conjunction with the metric 'percent of time audible' (US Forest Service 1992; Fidell et al. 1992; Anderson et al. 1993; Tabachnick et al. 1994; US National Parks Service 1994). Conversely work by Bjorkman et al. (1992) undertaken in Sweden in the vicinity of two urban airports concluded that the annoyance reaction is better related to the number of aircraft and Lmax than to Leq measurements.

Dose response studies undertaken in National Parks in the USA showed sensitivity to aircraft sound to be site and setting specific. It was concluded that with careful use, dose-response curves can predict where visitors are likely to be significantly impacted by aircraft sound. Once sites of concern are identified (based on the frequency of overflights, human visitation rates and the recreation opportunity intended), sound data can be collected and then compared with an appropriate dose-response curve for the site. (US National Parks Service 1994).

Constraints of Overseas Studies

Limitations and problems encountered by the studies reported here include:

- The sound monitoring studies undertaken by and on behalf of the US National Parks and Forest Services only recorded overflights. They did not record aircraft landing and taking off close to parks and wilderness areas. This may have resulted in an underestimation of impact for parks and wildernesses with adjacent airfields.

- In some cases aircraft peaks could not be obtained due to high ambient and low aircraft sound levels.
- In cases where an automated sound meter was programmed to record sound levels at a defined decibel trigger, aircraft may have been audible but not loud enough to trigger a recording. This would result in lower than actual 'aircraft only' Ldn results.
- Some automated 'aircraft' recordings could not be explained and may have been due to animals rather than aircraft.
- A great deal of wind noise was recorded under extreme weather conditions despite the use of windshields.
- Ldn calculations (where 10dB is added to night time dB levels) gave inaccurate results when daytime dB levels were not significantly higher than night time dB levels.

  (Bowlby et al. 1990; US Forest Service 1992; US National Parks Service 1994).

Findings of Overseas Studies

Conclusions drawn by the studies discussed and relevant to this study are summarised as follows:

- The maximum dBA sound pressure level recorded from the single loudest (acoustic) overflight, controls the daily integrated noise exposure of many wildernesses.
- Aircraft overflights were audible even when their A-weighted sound pressure levels were comparable to the A-weighted level of indigenous sounds.
- Few people were significantly impacted by overflights. However, annoyance due to aircraft was more strongly related to noise than to visibility or condensation trails, and natural quiet was concluded to have significant value to visitors.
- Dose-response studies showed a definite increase in response with an increase in dose.
- Implications were that: by decreasing the sound exposure, impacts decrease; some areas/settings are more important to protect from aircraft overflights than others; and that the maximal acceptable percentage/number of people impacted at a site can be set. (US Forest Service 1992; US National Parks Service 1994).

Recommendations for future management of protected areas experiencing aircraft overflight problems included:

- Expansions of flight free areas over parks, capping flight numbers and using curfews;
- Exploiting natural attenuation and therefore minimising altitudes where terrain can be used as an acoustic shield (although this increases sound levels directly below the flight path) while increasing altitude where terrain can't be used as a shield;
- Encouraging noise reductions at the source either by using quieter aircraft or retrofitting existing aircraft;
- The use of greater payloads and noise budgets;
- The improvement of regulations and the use of voluntary agreements between park authorities and tour operators; and
- Acoustic monitoring programs with defined triggers and action plans.

The point was made that solutions should be sought at the local level due to the unique nature of different situations (US National Parks Service 1994).