DISCUSSION

Trends in Aircraft Use

Results of the analysis of aircraft sound and activity at Whitehaven Beach are of the most value to management when placed within the context of other sound sources and activities as well as the relative use level at the time of the field survey. Figure 5.1 depicts trends in aircraft use of Whitehaven Beach from July 1997 until June 1998. Assuming that the same relative levels of use occurred at the time of the field survey for this study, the results of this study (data collected in October and December 1998) represent lower levels of aircraft noise and activity experienced at Whitehaven Beach over a year. This conclusion is supported by local knowledge (McLeod, *pers. comm.*, 1998).

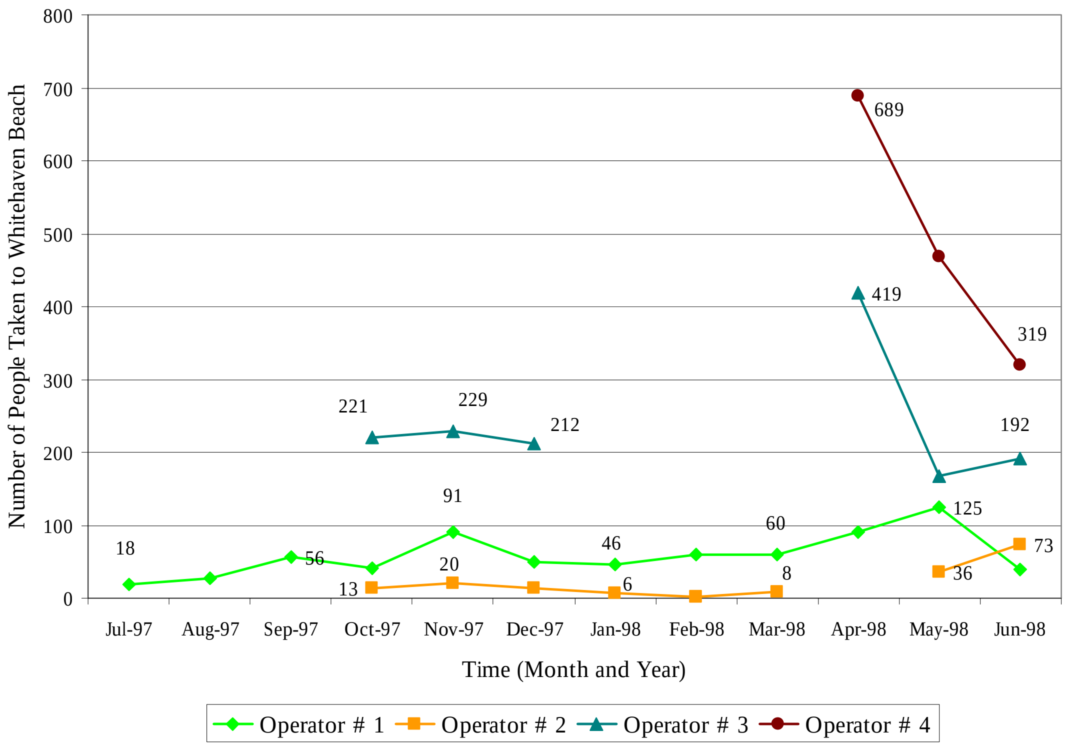

Figure 5.1. Trends in use of Whitehaven beach by several air tour operators *(Source: GBRMPA Environmental Management Charge Data)*

Discussion of Results

Noise and the ROS Spectrum.

Recreation opportunity spectrum settings are designed to provide a range of user experiences aimed at satisfying a variety of user expectations. In order to do so, all variables influencing the setting type need to meet the expectations laid down by the setting definition. Thus in the case of Whitehaven Beach one would expect the high use setting to receive the highest levels of use by all user types followed by the moderate use setting, the natural setting and the protected setting which would receive the lowest levels of use. Indeed, as detailed in the description of the study sites, the Whitsunday's Plan of Management (GBRMPA 1998) defines the ROS settings in these terms.

The results of this study show that in the case of aircraft at Whitehaven Beach, site 2 (representing the high use setting) experienced both the lowest levels of visitation, duration of aircraft sound levels above background sound levels and proportion of aircraft visits registering above background sound levels. Average Lmax sound levels at site 2 were slightly higher than those recorded at site 5 (protected setting). Sites 3 (moderate use setting) and 4 (natural setting) experienced the highest numbers of visits, highest average Lmax sound levels and longest durations with equivalent proportions of aircraft visits registering above background sound levels as at site 5. Subsequently, in terms of aircraft activity and noise levels along Whitehaven Beach, a trend inconsistent with that predicted by the definitions of the settings within which the sites are situated is apparent.

As the aircraft landing zones along Whitehaven Beach occur in the moderate and natural settings (although aircraft were observed to land and takeoff in all settings), it is not surprising that these settings receive the highest levels of aircraft use and noise exposure. This issue is related to planning, as landing zones have been established in settings designated to experience very few aircraft visitations. The presence of a landing zone on the northern side of Hill Inlet within setting 5 further contradicts the description of Hill Inlet as being protected from access by aircraft (GBRMPA 1998). Furthermore, the small size of the ROS settings along Whitehaven Beach is expected to reduce their ability to maintain distinct characteristics in line with their definitions. The fact that motorised water sports and aircraft landings / takeoffs were observed to occur beyond their designated areas of activity would also have influenced results and highlights a problem of regulation enforcement.

The main difference in human and watercraft use of the beach occurred between site 2 (high use setting) and all other sites, with site 2 experiencing much higher levels of use than all other sites. Thus for these variables the ROS spectrum appears to be functioning in line with expectations. However, a gradient in human and watercraft use in line with the definitions of the ROS settings was not apparent between sites 3, 4 and 5.

Noise and Time of Day

The recreation opportunity spectrum is primarily a method of spatial planning, however, temporal planning, using methods such as curfews and seasonal restrictions, is often incorporated into it. Thus, the same spatial area may undergo a range of use regimes relative to time. Seasonal restrictions and curfews are currently in use in the Whitsunday Islands (GBRMPA 1998) (McLeod *pers. comm.*, 1998) and the settings along Whitehaven beach experience temporal changes in levels of use due in part to regulations governing times of use.

The busiest time of day for aircraft at Whitehaven Beach was recorded as being in the morning peaking between 11:30 and 12:30. The longest durations of noise were also recorded within this time frame. However, the loudest average sound recordings made at each site did not show a unified trend relative to time of day. Rarely were aircraft observed before 07:00 or after 17:00.

Many more people were recorded as being on the beach at 14:00 than at 10:30 and observations showed that most of the people present in setting 2 at 14:00 arrived in the hydrofoil *'Fantasea'* at roughly 13:00 and left the beach at approximately 16:00. Few people or watercraft were present on the beach or in the bay before 09:00 or after 17:00.

Aircraft versus Watercraft.

As mentioned earlier, results of the analysis of aircraft sound and activity at Whitehaven Beach are of the most value to management when placed within the context of other sound sources and activities. In the case of anthropogenic noise at Whitehaven Beach the two sources assumed to be most obvious to recreationists are watercraft and aircraft. However, comparisons of the potential intrusiveness of these noise sources are not straight forward.

The absolute maximum watercraft induced decibel level recorded was 79dBA compared to 98dBA recorded for aircraft. This suggests that aircraft have a greater noise impact. However, maximum decibel levels and audible duration are potentially equivalent variables impacting recreationists at Whitehaven Beach. Although the duration of watercraft noise events was not rigorously measured (as the focus of the study was on aircraft), the longest duration recorded for a single watercraft noise event was almost twice that recorded for the longest single aircraft noise event. This suggests that although watercraft emit lower maximum sound levels than aircraft, their average duration may be longer. Subsequently, watercraft potentially have an equivalent or greater sound impact than aircraft.

Mitigation

Methods of noise mitigation was not a focus of this study although mitigation methods used in and recommended for National Parks in the USA were discussed in the review of related studies. One method of mitigating noise of both overflights and takeoffs is derived from the relationship between distance from the sound source and the sound level experienced by a listener. This relationship was investigated at Whitehaven Beach for seaplane takeoffs. Results showed that all maximum sound levels above 89dBA were recorded when the aircraft was within 300m of the recorders, and all maximum sound levels below 78dBA were recorded when the aircraft was 500+m from

the recorders. Thus, as an increase in ten decibels is perceived as being twice as loud (Standards Australia 1988), this result suggests that a relatively short increase in the distance between a takeoff and an observer (e.g. from 300m to 500m) potentially reduces the noise impact by at least half. This also raises the issue of other mitigation measures including, quieter aircraft technology, noise budgets and the expansion of flight free areas.

Technology, Survey Design and Analysis

Ideal Technology

The Techcessories analogue sound meters upon which differences in sound levels between sites were based did not meet Australian Standards for either type 0, 1, 2 or 3 sound level meters. However, as stated in the Standards, they may be considered satisfactory for particular applications (Standards Australia 1988) which presumably includes indicative studies such as this one. The integrated type 2 meter used to give comparative and theoretically more accurate readings was itself past calibration date and when tested shown to be reading 1.8 dB lower than it should have been. Thus, it too did not meet Australian Standards. Subsequently, results from this study are only indicative of sound levels experienced at Whitehaven Beach and can legally only be used to help decide the need for more comprehensive research.

Preferably the sound meters used would have at least met the Australian Standards for type 0 or 1 meters including specifications for use in the field. Sound meters specifically designed to accurately measure sound levels below 20 - 25dB (and therefore capable of establishing the level of extreme quiet) would have been even more ideal.

Survey Design

Strategy

This study was constrained due to the small size of the study area. The proximity of measurements to one another meant that they were not truly independent of each other, thus limiting the use of quantitative analysis. Used on a larger spatial scale such as the whole of the Whitsunday Islands, the survey methodology would be expected to be more meaningful. However, as the main objective was to determine differences between settings along Whitehaven Beach, it was unavoidable that data collection sites would be in close proximity to one another as the adjoining settings themselves are only between 1 - 2 kilometres wide. This highlights the point that ROS was originally intended for use on a regional scale (Manning 1986). Use on a larger scale can be assumed to result in less edge effect within setting areas and a better means of satisfying diverse users.

Data collection sites were not replicated within each setting. Thus results only represent conditions at the site within the setting at which measurements were made. Although these conditions can be hypothesised to represent the setting overall (or at least the core of the setting), this study provides no substantiated evidence of this.

Logistics of Data Collection

Sound Recordings

As sites were not necessarily equidistant from the high tide mark this may have affected background readings and the level to which aircraft sound was masked. The inability to always eliminate wind noise readings from the calculation would also have influenced sound level recordings. Sound made by the data recorders while making analogue recordings may have influenced integrated type 2 sound meter recordings.

Sound meter calibration errors may also have affected results. All sound meters were calibrated prior to and after each field trip. After the second trip the sound meter for site 4 was reading 0.5 dB lower than the others. Results were not adjusted accordingly due to the inability to determine when this difference in reading occurred while for the purposes of this study a difference in 0.5dB is not considered crucial to the main results.

A-weighted networks and fast response settings were used for all sound recordings. Fast response settings were certainly necessary when recording aircraft and watercraft sound levels as one of the aims was to determine peak levels. Slow response settings may have been a better means of establishing background sound levels. Using a slow response would have eliminated much of the affect of outlying readings and given a truer average.

Significant Watercraft Events

Sites may not have been equally likely to record 'significant' watercraft events while the definition of a significant watercraft event was subjectively determined by data recorders. Sites experiencing higher numbers of aircraft events presumably had less time to record watercraft events, subsequently biasing the results. Notably site two experienced the lowest number of aircraft events while recording many more watercraft events than any other site. Nevertheless, the result for site 2 has a great deal of room for error while continuing to remain substantially different from the other sites. Also, results are consistent with the personal observations of the researcher plus those of Ormsby and Shafer (1999), who found setting 2 to be the most frequently visited setting by both people and watercraft.

Individual Variability

Individual variability in methods of data collection probably influenced results. Variability due to differences in eye sight and hearing of the observers may have resulted in differences in the methods of recording the number of aircraft events. This is probably especially true for sites 3 and 4 which, due to their location in the middle of the beach, were inclined to be border line for experiencing one versus two events. For example, an aircraft flies over a site and later returns to land but is recorded as one event because it remained within audible/visual range despite having two distinct peak sound levels. Also, when taking sound level readings, observers may have had a tendency to read even rather than odd numbers as even numbers were more clearly defined on the analogue sound meters.

Estimations of duration are considered to be the variable most influenced by variations in data recorder technique. Some individuals were observed to be more conscientious

about recording the full length of an aircraft event than others. Furthermore aircraft could not be recorded from before they came into hearing range or even from when they first came into hearing range. The amount of time lost being partially dependent on the response rates of the observers. At least 10 seconds is estimated to have been lost for most events.

When establishing the relationship between aircraft takeoffs and distance from the beach during the third data collection trip, error may have occurred due to discrepancies between the timing of sound and distance readings. Although these were intended to be taken concurrently, variations in the order of a few seconds very likely occurred.

Analysis

Descriptive

Sound

Results of aircraft sound variables are compared with the overall mean background sound level of 57dBA. If this level is lowered to 52dBA (the mean suggested by measurements made with the integrated sound meter), values of the variables: durations of aircraft sound; overall proportion of aircraft visits registering above background sound; and the difference between natural and aircraft sound levels, increase at all sites.

Limitations of the A-weighted network as discussed in appendix 7.2 may have resulted in an underestimation of the loudness perceived by observers. However as the A-weighted network has been used in all related studies so far, results are comparable to these studies. As discussed in appendix 7.5 in reference to Anderson and Horonjeff (1992), the use of the acoustical descriptors Lmax and Leq versus audibility metrics, potentially result in a conclusion of less value in increasing altitude for mitigation purposes. However, in light of the high ambient background sound levels experienced at Whitehaven Beach as a result of surf and wind, increases in altitude can be expected to result in a significant reduction in sound impact, when impact is measured using audibility metrics (e.g. percent of time audible).

As only 19% of aircraft events definitely started from and returned to background sound levels this implies that 'duration above background' was a relatively inaccurate variable to measure. Possibly either because events had durations greater than those recorded or because higher than average background sound levels interfered with the calculation. The method of multiplying the number of readings registering above average background sound level by a factor of 10 in order to estimate duration, also has room for error as sound levels did not necessarily steadily increase and then decrease during an event, some fluctuated substantially.

Duration of aircraft induced sound levels above background sound levels is also considered to be unreliable as a means of indicating potential levels of noise impact on recreationists at Whitehaven Beach. This is primarily because aircraft were observed to be audible for much longer than they are recorded as being above background sound levels. This observation is consistent with the results of studies done in the US (US Forest Service 1992; US National Parks Service 1994).

Environmental Conditions

Site four, the site at which wind data was collected was assumed to be representative of wind regimes over the entire beach. However, given the non-uniform topography of the beach, this assumption may not be valid.

Trends in Activity

Trends of aircraft activity are extrapolated from trends in the numbers of people taken to Whitehaven beach by aircraft. Although there is undoubtedly a positive correlation between these two factors, there is also room for error.

Statistical

Conclusions drawn by this study are primarily based on descriptive results. Where statistical tests have been undertaken, their validity is dependent on the accuracy of assumptions about the data as referred to in the summary of results section. The use of analysis of variance is based on an assumption of normal or approximating normal distribution which was tested whenever analysis of variance was used.

The use of non-parametric statistical tests to compare results of sound levels and numbers of events between sites, was primarily inhibited by the inability to assume independence of the samples due to the proximity of the sites to one another.

Measuring Impacts (Sound or Noise)

In order to measure impacts of aircraft noise on recreationists rather than just the environmental phenomenon sound or its related variables, it is necessary to directly correlate sound levels or related variables with human response. Thus, concurrent studies such as those by Fidell et al. (1992), Anderson et al. (1993) and Tabachnick et al. (1994) and discussed in the review of related studies, need to be undertaken. In these studies sound metrics such as 'percent of time audible' and 'Leq' were measured concurrent with onsite interviews taking place. Thus, allowing dose-response relationships to be established.

If a dose-response relationship was established for Whitehaven Beach, it would then be possible to predict impact in similar areas by measuring sound / noise variables. As studies done in the USA have shown that the sound metric 'percent of time audible' most accurately indicates level of response, it may not be necessary to use sound meters at all to develop a dose-response curve for aircraft noise at 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. Unfortunately this study and that of Ormsby and Shafer (1999) were not undertaken at the same time and so the results cannot be directly correlated. Aircraft activity was lower during Ormsby and Shafer's data collection period and weather conditions were poorer. Dose response studies undertaken in the USA did show that an increase in dose resulted in an increase in response (US National Parks Service 1994) and Brown's (1986) work at Green Island supports this. Thus it is fair to assume that a similar scenario is likely to occur at Whitehaven Beach.

Recommendations for Future Studies

Recommendations for future studies in the Whitsunday Islands and Australia generally are based on four factors: sound meters; sound metrics; survey periods; and the positioning of sites.

As discussed in appendix 7.1 sound meters should at least meet Australian Standards for integrated types 0 or 1 including specifications for use in the field. Results obtained would then meet legal requirements for decision making in Australia. However it would be preferable to use sound meters capable of measuring sound levels below 20 - 25dB (the usual limit for sound levels used in community sound studies) (Horonjeff et al. 1993; US National Park Service 1994). If analogue Techcessories sound meters (or an equivalent sound meter type) are used again for indicative studies, the use of a slow response setting to measure background sound level averages is recommended as well as the use of windshields at all times.

Sound metrics used (refer to appendix 7.3) depend somewhat on the type of sound meter. Integrated sound meters would allow the measurement of Leq and the subsequent calculation of Ldn. Comparisons between 'total' (all sources) Ldn and either 'aircraft only' or 'indigenous only' Ldn could then be made, as discussed in the methods used to monitor and assess overflights section, in reference to work reported by Bowlby et al. (1990) and the US Forest Service (1992). Sound meters could also be programmed to record once a trigger sound level was reached and subsequently the study would not heavily rely on volunteers to collect the data. The use of the sound metric 'percent of time audible' is highly recommended particularly in the absence of high quality sound level meters. Use of the metric 'percent of time audible' would; simplify data collection, reduce reliance on expensive technology, and provide a means to most accurately predict human response. However, data collection using the metric 'percent of time audible' would heavily rely on the availability of volunteers meeting set hearing requirements. The use of either the metric 'Leq' or 'percent of time audible' undertaken concurrently with social surveys would allow for the development of dose-response curves.

Periods of data collection complying with those recommended by DeVor et al. (1979), Schomer and DeVor (1981) and Schomer et al. (1983) and used by Bowlby et al. (1990) (discussed in appendix 7.4) are also recommended. Possibly four week long periods corresponding to distinct seasons of use.

Data collection sites should be replicated within settings and placed over a wider spatial scale to ensure independence between them. If reassessing sound levels along Whitehaven Beach, other sites within equivalent settings at other locations in the Whitsunday Islands should also be assessed. Replication within settings which are geographically independent would also allow an assessment to be made of the consistency in characteristics between settings of the same type.