Lower Gordon River turbidity monitoring, April 2003 – December 2004

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Summary and recommendations
Turbidity monitoring indicates that boating continues to cause bank erosion on the lower Gordon River. The magnitude, frequency and timing of events in both daily and seasonal terms indicates that commercial cruise vessels have greatest collective impact. The effect of private visitors is variable and in some cases disproportionately large. Management response is necessary if sustainability is to be achieved and should involve implementation of two previously proposed measures:

- more appropriate criteria for licensing of commercial operations (wash rule) and revision of speed limits for existing commercial vessels,
- active discouragement of other boating visitors from travelling at a speed greater than approximately 5 knots.

These recommendations are discussed in more detail in a companion report*: Revised wave wake criteria for vessel operation on the lower Gordon River* (Bradbury 2005).

Background

The lower Gordon River in south west Tasmania has bank landforms of world heritage value that have been significantly eroded by vessel wave wake for two decades. Erosion appears to have begun suddenly in the mid 1980s when large, fast tourist cruise vessels replaced earlier boats. Prior to then the banks had generally been either actively depositional and encroaching upon the channel or stable for at least 1400 years. The Tasmanian and Australian governments agreed to commercial vessel speed and access restrictions in 1989. Speed limits on boats licensed by the Parks and Wildlife Service were again reduced in 1994 and around 1998 a maximum wave height criterion was introduced when operators indicated a preparedness to commission 'low wake' vessels to replace a then aging fleet.

Erosion pin monitoring began in 1987 and has shown a decline in erosion rate coincident with each of the three major management changes, providing evidence that wave wake is a significant driver of contemporary geomorphic process. When erosive wake waves hit the bank fine sediment is suspended and may be removed from the landform system by currents. Experimental work focussed upon characterisation of wave wake in terms of potential erosion examined formation and dispersion of the turbid clouds that indicate operation of erosive mechanisms.

Around 2002 interim re-evaluation of cruise fleet wave wake characteristics against empirically determined thresholds of erosion suggested that permitted speeds were typically about 0.5 kt faster than required to achieve the management target of zero erosion by wave wake set by the Lower Gordon River Recreation Zone Plan (1998). Testing of that hypothesis required monitoring of erosive events with far greater temporal resolution than afforded by the pin monitoring programme. This has now been achieved by logging bank proximal turbidity at 15 second intervals at a site where geomorphic response to wave wake is known from both pin monitoring and experiments. The hypothesis remains unfalsified and results indicate that further management action is required.

Methods

This report documents trial of an apparently novel environmental monitoring technique so methods are described in detail. The equipment consists of an analogue Analite NEP 195, a 90 degree backscatter infrared turbidity sensor factory calibrated in the range 0 – 100 NTU (nephelometric turbidity units) and with reasonably linear output to 400 NTU. The instrument is fitted with a wiper to keep the optics clean, which is activated by a signal from the data logger once an hour. The logger is a Unidata model 6003 with 128 kb internal memory and a 1 Mb memory card. The maximum input is 2.55 V, corresponding to 255 NTU, any off-scale readings are logged as 255 NTU. Analogue to digital conversion is at 10 bit resolution however to minimise memory requirements storage is at 8 bits, corresponding to approximately 1 step per NTU.

Although most of the hardware is nominally available 'off-the-shelf' the sensor – logger interface was designed and constructed on prototype board from discreet components. The installation has failed to achieve the specified rate of power consumption but a fix is planned. This issue does not affect accuracy of readings but means the instrument battery pack is generally exhausted before it can be conveniently replaced, leaving gaps in the record (figure one).

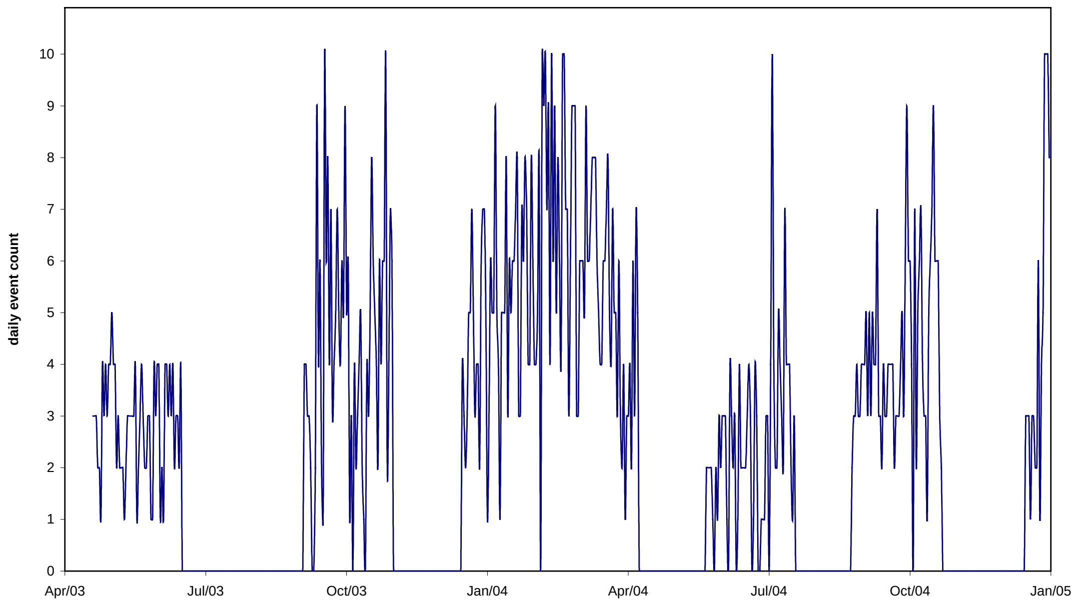

Figure 1: Daily tallies of erosive wave wake events over the trial monitoring period

With 5760 measurements acquired daily the turbidity monitoring is more numerically intensive than many other environmental monitoring techniques. The data is translated from the binary storage format and exported from the logger software as an ASCII file of date, time and turbidity value and analysed using Microsoft Excel and VBA macros (see screenshot, figure two). The large download file is then split according to the date string into a daily series of 130 kb files for processing. Initial analysis may be conducted in the field and in case of anomalies cross checked against erosion pin measurements to guide troubleshooting or geomorphological observation.

Time series measurements of turbidity caused by wave wake may be characteristically spikey due to transit of floating organic debris past the sensor. A simple filter is therefore used to smooth the signal if an adjustable rate of change (gradient) is exceeded. Wave wake impact is signaled by a distinctively abrupt onset and maxima followed by exponential decay over several minutes or longer. No natural process is known that would produce turbidity peaks with these characteristics, with the possible exception of intermittent localised bed disturbance by an animal such as a platypus or duck. The sensor also occasionally detects sediment input from tributaries during rainstorms and is prone to occasional 'tidal' emergence and submergence, producing strong signals due to internal reflection when the water surface forms a meniscus upon the optics. Any signal of these sorts must be manually excluded from the daily record before applying a peak detection algorithm to analysis of wave wake events. Peak detection is achieved by specifying:

- minimum maxima as a multiple of signal mean
- onset and cutoff thresholds in terms of signal percentile
- minimum integral between signal curve and specified thresholds

The algorithm then identifies the onset and tail end times of the highest peak and excludes that portion of the record before searching for the next highest peak and so on, for up to 10 peaks. More than 10 daily peaks are evident only a few times a year. Following inspection adjustment of peak detector settings is often necessary to prevent assignation of multiple peaks to the signal from a single event. Sometimes inspection also suggests onset of a second peak before the turbid cloud due to an earlier event has subsided below the cutoff value, so peak onset can also be manually flagged. In the analysis presented here the above settings may be varied between days but are constant for all peaks on any one day so that smaller, later peaks may become increasingly difficult to detect.

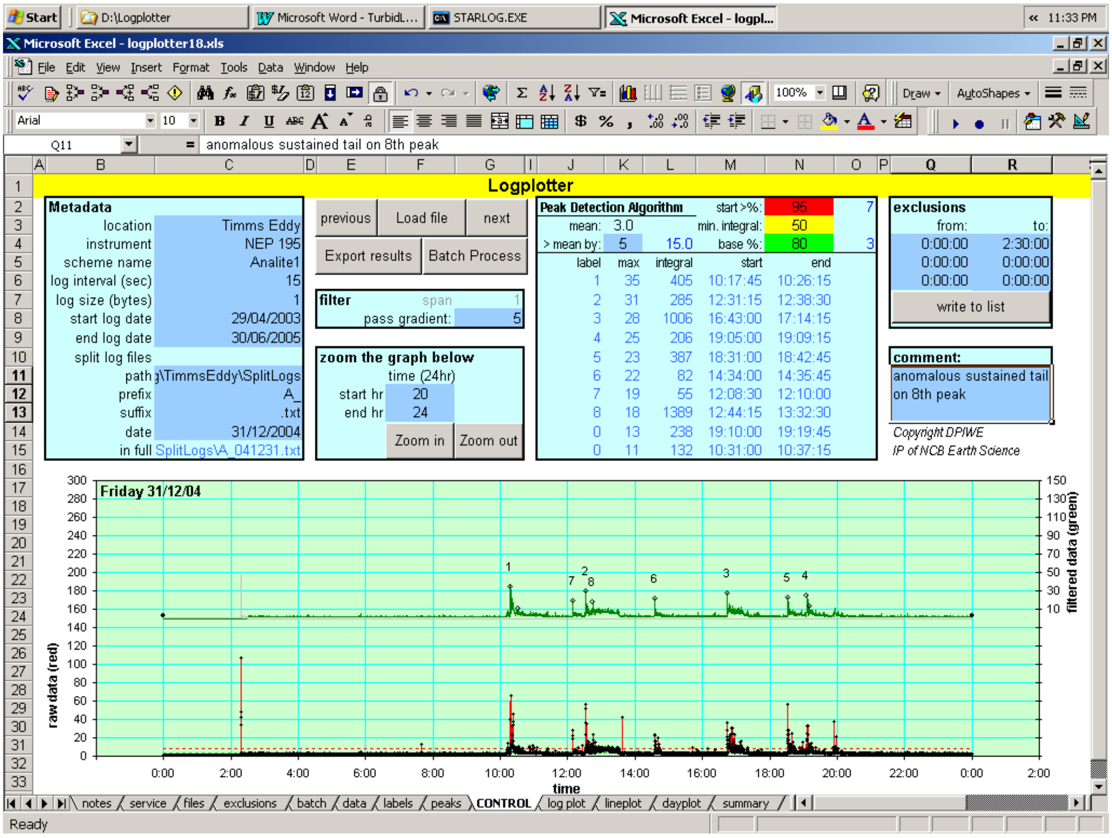

Figure 2: Screenshot of the data analysis spreadsheet showing early morning tidal submergence and eight numbered wave wake events, with details tabulated in the peak detection algorithm box. Peaks can be examined in greater detail by zooming the plots according to adjustable start and end times.

Results

Daily pattern

Analysis identified 1489 turbidity events characteristic of wave wake impact from 358 days of record, an average of 4.2 per day. The timing of a large proportion of detected peaks is remarkably consistent (figure three) and corresponds with passage of scheduled cruises past the monitoring site. Timing is not offset by changes between summer and winter time so it would appear very unlikely that the regular peaks are the result of habitual animal behaviour or any other periodic natural event.

For most of the period of record two cruise vessels visited the lower Gordon River each day. Typically the first passed the monitoring site near Timms Eddy shortly after 10:00 am, heading upstream to Heritage Landing. That vessel would then return downstream past the site just as the second vessel was heading upstream. Overlapping turbidity peaks may be distinguished on many of the daily plots around midday although failure to resolve discreet peaks is more common. The second vessel then returns downstream past the monitoring site, typically around 2:00 pm.

A second set of four pronounced peaks between 4:00 and 7:00 pm is correlated with the 'afternoon' cruises that are run in the peak tourist season. Apart from the regular peaks there is a low background attributed to the passage of other vessels past the monitoring site. Very few events occur in the hours of darkness.

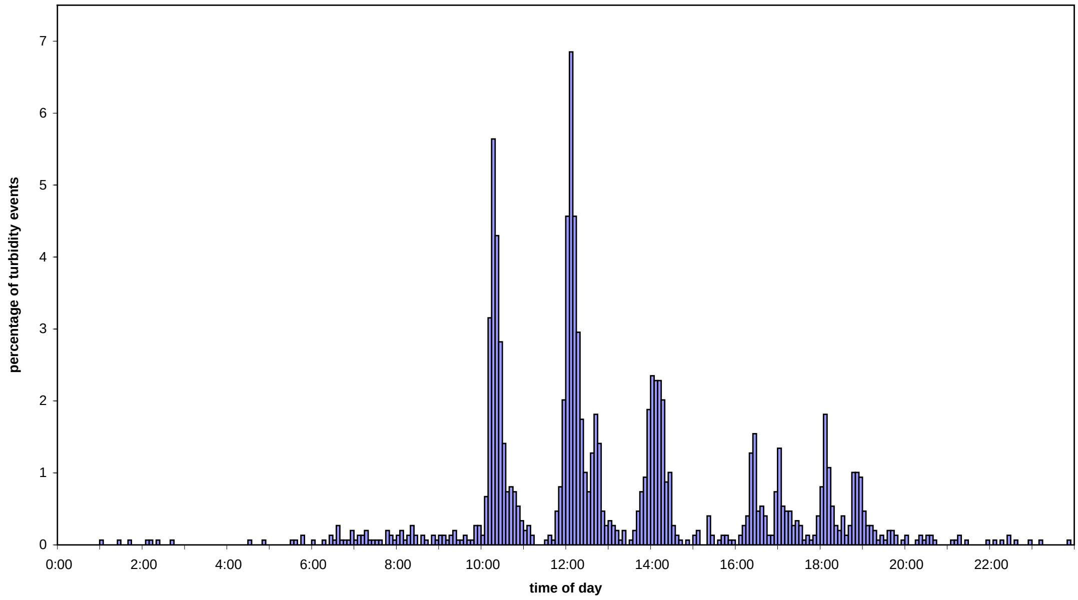

Figure 3: Histogram showing temporal distribution of wave wake events at 5 minute intervals.

Seasonal pattern

Due to gaps in the record the data has been pooled and normalised on a monthly basis to represent a hypothetical year in order to examine seasonal variation in river traffic. June, September and October are over-sampled while August and November are significantly under-sampled. Change in the average monthly event count (figure four) is consistent with known visitation patterns. The maxima in late summer reflects the busiest cruise and tourist boating season, elevated activity in the August - November period coincides with peak angling effort and the winter minima is not surprising. The relatively elevated event count in July is anomalous, that month is also under-sampled but not significantly.

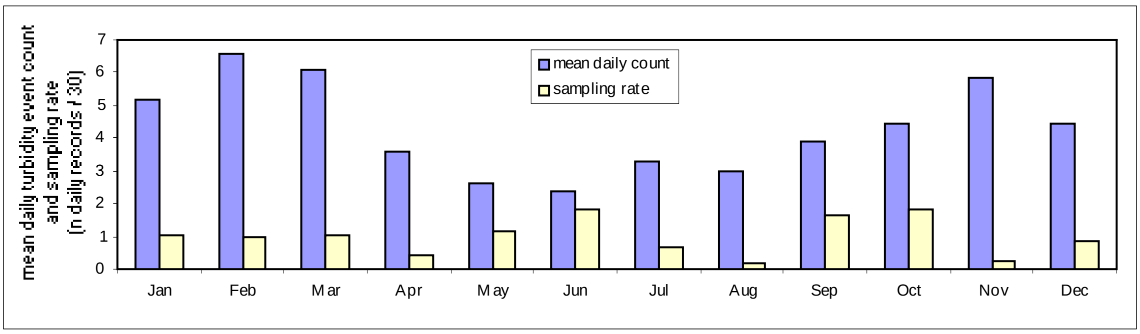

Figure 4: Histogram showing monthly distribution and sampling rate of wave wake events.

Discussion

Following the precedents of Downing *et al*. (1981) and Garrard and Hey (1987) turbidity has been measured as an indicator of sediment suspension by waves and the environmental impact of boating activity. Geomorphic response of the monitoring site to wave wake events was determined (Bradbury 1998) in a series of experiments similar to those of Bauer *et al*. (2002). Instrumentation has been further developed for deployment on a longer term basis in order to monitor the wave wake events that cause erosion at an appropriate temporal resolution. The installation is in effect a boat counter, tuned to detect only the traffic capable of geomorphic effect.

To achieve this 3.2% of the data string was excluded from analysis, whenever the signal was somewhat subjectively regarded as unrelated to wave wake. Much of the excluded data indicates 'low tide' periods of no signal bounded by signs of sensor emergence and resubmergence. This only happens under stable conditions of high atmospheric pressure so these exclusions are unlikely to hide any natural event of geomorphological significance. Some exclusions of up to 24 hours of otherwise unexceptional record stem from the fact that the analytical software cannot yet easily cope with relatively brief interruption of the data stream necessary for servicing of the installation.

The record also shows a small number of environmental turbidity events persisting for several hours or days which may have been due to either depositional input following heavy rain or erosion by storms of wind waves. Given that distinction between these types of events is only possible by correlation with meteorological observations and that gaps in the record may cover rare but geomorphically significant occurrences no attempt has been made here to quantify the relative contributions of environmental events and vessel wake to geomorphic change beyond the qualitative observation that wave wake remains significant

Analysis of identified wave wake events clearly show that scheduled cruises have the most frequent impact and therefore cause at least some of the erosion measured by pin monitoring at this and other sites. But how much? From figure three we can differentiate between events likely to have been caused by licensed and other vessels on the basis of timing. With 1489 events distributed across 288 daily intervals of five minutes over 51 weeks of record the approximate average annual number of events per time-slice is 5.2 (0.34%). Intervals with a record of less than average frequency of events may be considered the exclusive domain of unscheduled and largely private visitation. The remaining event clusters may then be regarded as times when a scheduled cruise is more likely than not the trigger of any specific event (figure five).

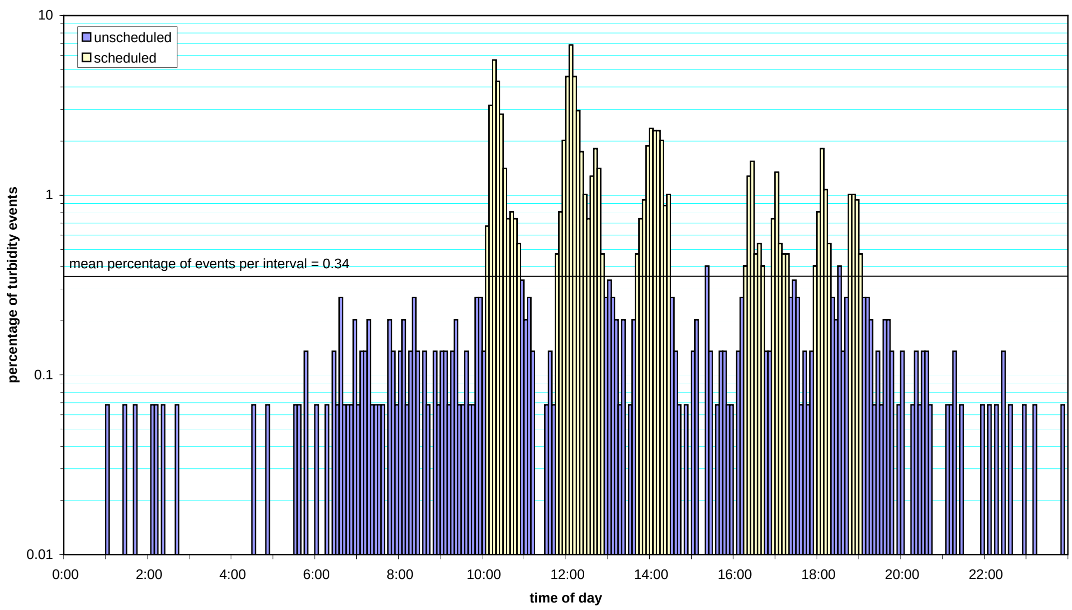

Figure 5: Differentiation between scheduled and unscheduled wave wake events.

The maximum turbidity value attained during a wave wake event is the most obvious indicator of impact, here simply estimated as the number of events per time-slice multiplied by the average peak value. This may then be plotted against time of day as a proportion of the total impact (figure six). From this we can see that 81.5% of total impact occurs at times when a cruise vessel is the most likely cause. The primary target for the management action necessary to achieve the aim of zero erosion by wave wake is thereby identified. Implementation of the wash rule and revision of speed limits for commercial vessels as per an accompanying discussion paper (Bradbury 2005) is recommended.

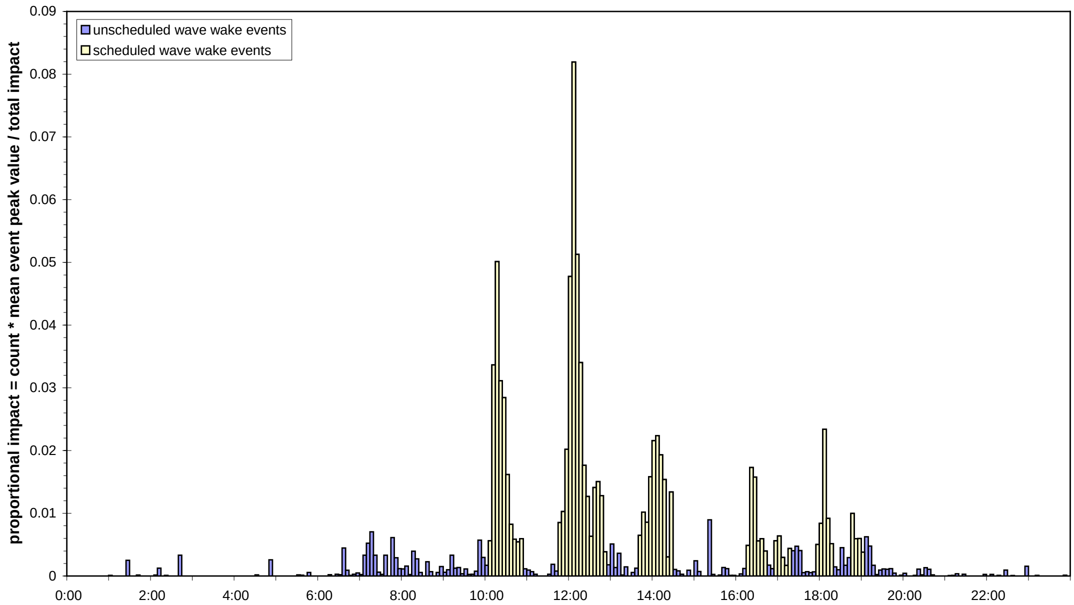

Figure 6: Histogram showing temporal distribution of wave wake impact at 5 minute intervals

A subtle difference between figures three and six is that unscheduled wave wake impact is not as evenly distributed as event count but concentrated around dawn and dusk. Events at these times appear most common in the angling season, which figure seven shows is roughly coincident with the period of greatest impact per detected vessel. Note that impact estimates for November are regarded statistically invalid due to the combination of undersampling (fig. 4) and a unique measurement error following environmental realignment of the sensor closer to the bed. Event count is not considered to have been greatly affected but amplification of normal background signals for about a week prior to battery failure suggests the magnitude of wave wake impact is overestimated.

It is possible that at least some of the annual variability in impact estimates is the result of seasonal changes in water level and surface water salinity affecting the sensitivity of the installation. The former influences the area of mud available for suspension by shoaling waves and the latter the flocculation of the resultant turbid cloud. Figure eight was plotted on the assumption that scheduled cruises would generate consistent wave wake but provides an inconclusive test because vessels from different operations do not cause simultaneous anomalies. Irregular variation in cruise operation, either in speed or distance between vessel track and site is therefore implied. It is speculated that this might be due to occasional substitution of vessels (WHC only) or masters.

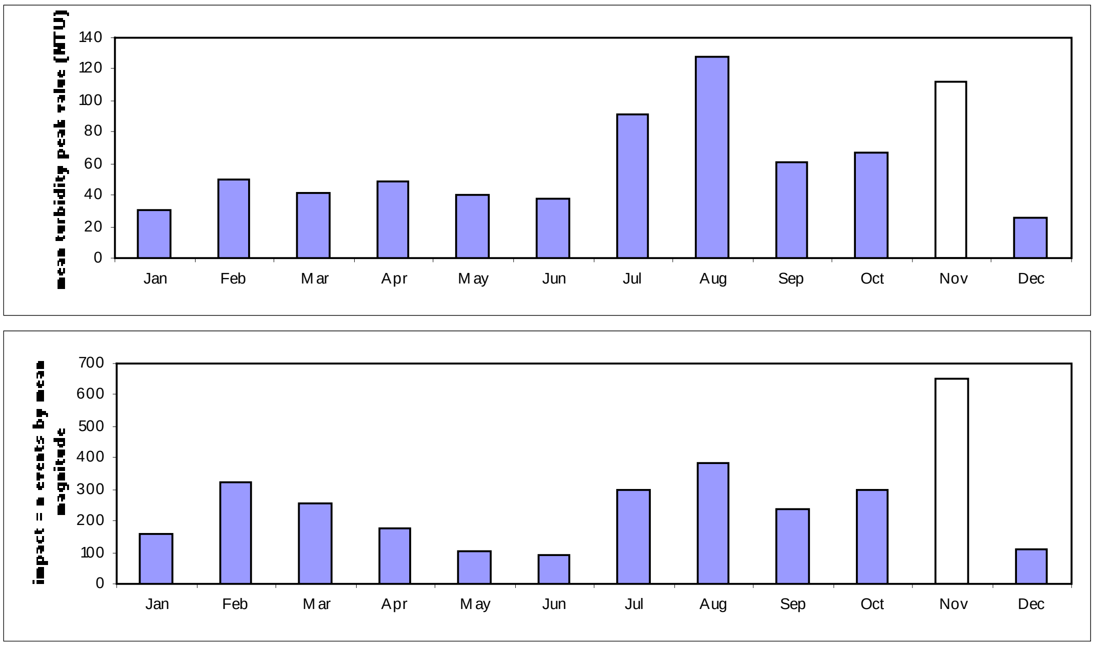

Figure 7: Histograms showing monthly mean wave wake event magnitude (top) and cumulative impact (bottom).

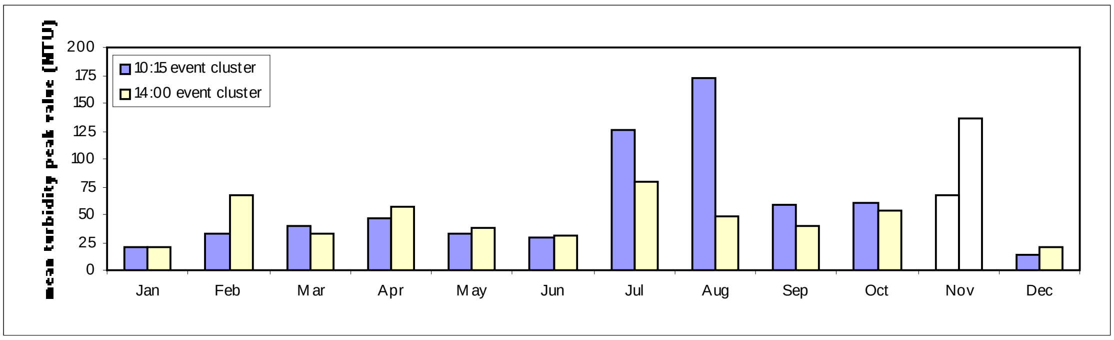

Figure 8: Histogram showing monthly distribution of wave wake event magnitude due to regular cruises by different operators. Note that absolute magnitude is not directly comparable due to opposite directions of vessel travel.

Summary

Three broad classes of traffic are recognised: cruises, anglers and summer boaters. Cruises cause the greatest cumulative impact but not every cruise creates a pair of turbidity event records, implying that under some conditions operations are sustainable. Potentially mitigating factors include vessel speed, distance from site, direction of travel, water level and salinity. The afternoon cruises typically cause less impact, implying diurnal variation in either sensitivity to wave wake or operating conditions. As a group anglers appear to have greater impact than summer boaters but this may be due to the manner in which vessels are operated by a small number of individuals. Some variability in seasonal sensitivity is also apparent but only operator behaviour can be addressed.

References

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Source data

Daily turbidity records have been plotted in detailed (4 days / page) and summary (3weeks / page) forms. These may provide further useful insight into the pattern of erosive wave wake events and are available upon request.