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Too much data is never enough: A review of the mismatch between scales of water quality data collection and reporting from recent marine dredging programmes

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ABSTRACT

Water quality monitoring programmes have become integral components of efforts to identify the impact(s) of anthropogenic activities. In many programmes, however, it appears records are being collected at finer temporal scales than required to produce the information needed by end-users (e.g. managers). Such mismatches are of concern given that the effort and expense invested in collection and processing of unexploited records is effectively wasted. Consequently, we were interested in reviewing the temporal scales over which water quality records have been collected, analysed and reported in monitoring programmes. Our case study focussed on turbidity (NTU) records collected from the monitoring of key dredging programmes ($n = 8$) initiated on the northern Australian coastline between 2006 and 2012. The review of (primarily grey) literature revealed that (a) there has been an increase in the number of turbidity records collected per day over time, a pattern driven by fine scale temporal records being taken at an increasing number of sites, and, (b) although these records are typically acquired multiple times per day for all loggers, a daily summary measure is commonly reported (e.g. median, rolling or exponentially weighted moving average), with some programmes reporting a subset of the spatial detail acquired (e.g. averages of dual loggers, exclusion of records from 'backup' stations). This pattern of analysis and reporting removes fine scale detail from summaries provided to end-users, driving monitoring programmes to become relatively 'data-rich but information-poor'. We suggest that iteratively designing monitoring programmes based on the outcomes of previous experiences could facilitate the collection of datasets with higher information content (i.e. fewer records that are not used to produce information), ultimately increasing the efficiency of future monitoring programmes.

1. Introduction

Environmental monitoring programmes are well established as a way to collect ongoing information for tests of hypotheses regarding the influence of human-driven processes on the environment (Houston and Hiederer, 2009). While monitoring programmes can represent an important source of information, some show symptoms of 'datakleptomania' (*sensu* Hellawell, 1991) – a syndrome characterised by the uncontrolled desire to collect ever more data, with the reasoning that more data can only ever be a good thing. While a positive effect of datakleptomania is that monitoring programmes are less likely to not obtain sufficient data to test hypotheses with statistical power, a negative is that where hypotheses could be adequately tested with fewer data, resources will have been wasted in collecting, processing and storing data – resources which may have been better used elsewhere, perhaps testing other equally important but unaddressed issues (Rose and Smith, 1992; Strobl and Robillard, 2008; Houston and Hiederer, 2009). In essence, the desire to collect ever more data can mean monitoring programmes are perpetually at risk of becoming 'data-rich but information-poor' (*sensu* Ward et al., 1986), with the information presented to end-users representing a subset of that actually acquired during monitoring programmes (Houston and Hiederer, 2009; Hanley, 2012). As a result, there are increasing calls for more critical thought about data collection, specifically the match between the scales of collection, analysis and reporting (see, for example, Timmerman et al., 2000; Hanley, 2012).

As marine ports are developed to facilitate the transport of resources, including oil and gas, monitoring programmes have been conducted to quantify the impacts of associated dredging (as has occurred, for example, in northern Australia; Commonwealth of

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Australia, 2012). A key environmental feature which may be altered by such dredging is turbidity of the water column. Where turbidity is modified, this change has the potential to decrease light availability and increase sedimentation rates, limiting the growth and metabolic processes of various organisms including seagrass, algae, coral and larval fish (Erftemeijer and Lewis, 2006; Erftemeijer et al., 2012; Evans et al., 2012 and references therein). Consequently, management agencies, and the scientists they work with, are under growing pressure to understand the influence of dredging on turbidity (Hanley, 2012).

The need for sophisticated monitoring of turbidity associated with dredging programmes has catalysed the use of new technologies which allow remote collection of records at increasingly fine scales (Glasgow et al., 2004; O'Flynn et al., 2010; Hanley, 2012). For decades, field measurements to assess environmental conditions had depended on time-, labour- and finance-intensive on-site sampling and data collection (Hanley, 2012). With the development of in situ loggers, however, it is now possible to simultaneously sample over large and small temporal and spatial scales (Glasgow et al., 2004; O'Flynn et al., 2010). Further, while records can be down-loaded on-site, the advent of telemetry means records can also be accessed remotely in what is essentially real-time (i.e. downloaded every 10 min; MScience, 2009). Specifically, the development of LTD (light, turbidity, deposition) loggers has enabled fine scale quantification of various water quality parameters including not only turbidity (NTU) but also light (PAR), water depth (m) and sediment deposition (mg/cm^2/day) (Thomas and Ridd, 2005; Chevron Australia, 2011). While such technologies can be utilised to rapidly detect changes and trends in critical indicators and share that information with stakeholders (Glasgow et al., 2004), it has been suggested that, due to the ease and economy with which data can be collected, there are less rigorous discussions about why so much data is being collected and how it will ultimately be utilised (Hanley, 2012). Consequently, technological developments may be enabling the collection of turbidity data at much higher resolutions than actually required to address the questions monitoring has been commissioned to address.

We were interested in examining the scales over which water quality has been measured in recent water quality monitoring programmes and how this contrasted with the scales at which monitoring records were analysed and reported. Given the large number of monitoring programmes which have been conducted in northern Australia over the past 8 years, this is a good model system to use in such studies. Therefore, we focussed our literature review on the monitoring programmes and collection of turbidity (NTU) records from key dredging programmes on the northern Australian coastline. For these programmes we wanted to determine whether the records collected were needed to produce information reported to end-users or if acquired detail was removed from such summaries. If all the information collected was included in reports, it would highlight how technological developments have facilitated the development of monitoring programmes with appropriately high resolution. If detail was removed, however, it would suggest that either there are hypotheses of interest (about fine scale patterns) which are not actually being addressed in the reporting from monitoring programmes or that the monitoring programmes are products of 'datakleptomania' and so could possibly be redesigned to increase their efficiency.

2. Materials and methods

We reviewed the monitoring of dredging programmes recently conducted on the northern Australian coastline which have quantified turbidity (NTU). In total, this case study included details of eight monitoring programmes, with start dates ranging from 2006 to 2012 and locations in northern Australia ranging from Western Australia (Cape Lambert – Port A and B, Pluto, Gorgon, Wheatstone) to the Northern Territory (Darwin Harbour) and Queensland (Hay Point, Gladstone) (for summary see Tables 1 and 2). The details reported regarding these programmes were obtained primarily from the grey literature, all of which was available publically, with most documents publicly accessible from the websites of the energy and resources companies that were developing the ports. There were additional programmes we would have liked to include given their relatively large dredge volume and potential impact (e.g. Dampier Port, 2003, dredge volume 4.6 Mm^3 and Port Hedland, 2005, dredge volume 3.3 Mm^3; Hanley, 2011), but we were unable to find the required information (e.g. detailed dredge management plans) for these completed programs in the public arena.

In order to address the first component of our review, the temporal resolution at which records were collected, for each programme we identified the number and type of sites considered (as classified in the literature, i.e. high impact, moderate impact, impact, compliance, sentinel (uncertain), influence, reference, supplementary, reactive, non-reactive, with these terms defined in Table 1), interval at which records were collected, number of records collected per day, duration of dredging and total number of records for each programme. For the second component, which considered the temporal scale over which data was acquired, analysed and reported, we included information regarding seven dredging programmes (Hay Point was excluded due to insufficient information in the literature). For these monitoring programmes we identified whether the records were telemetered, the interval at which records were downloaded and which measures were reported to end-users. Where possible we also indicated the statistical treatment of the reported data (e.g. smoothing), and made a note of any additional data that was included in the appendices to the main reports.

3. Results

The key findings of the review were that (a) there has been an increase in the number of turbidity measurements collected over time, a pattern driven by measurements at an increased number of sites while the frequency of measurement within sites remained relatively constant and, (b) although the maximum collection interval was 30 min, the reporting interval was commonly 24 h (or 1440 min).

In terms of the total number of measurements collected, when finished these dredging programmes will have collectively monitored turbidity for a combined total of 149–155 months, at 111 sites and acquired over six million records (Table 1). The large number of records collected was largely driven by monitoring of the later programmes, with the two which started in 2012 (Wheatstone and Darwin Harbour) contributing approximately two and a half million records between them (Table 1). While some of the influence of these later programmes was due to their relatively long durations, the number of measurements collected per day (which removed the influence of the duration of dredging programme) has also increased over time; the programme with the latest end date (Darwin Harbour, 2012) was responsible for over three times the number of measures per day as the programme with the first start date (Hay Point, 2006) (Fig. 1a; Table 1). Interestingly, the increase in measurements per day over time was largely driven by increases in the number of sites quantified, rather than changes to the frequency of measurements. This pattern occurred because the average number of sites increased from 7 ± 2 (mean $\pm$ SE) in the first three years considered (2006–2008) to 21 ± 3 in the final