Fine sediment research issues in the Motueka River in the ICM programme: bringing the geomorphology and biology together
How are we progressing?

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Introduction

When the sediment research in the ICM programme was formulated, the primary goal was

> *"to develop an understanding (and ultimately model) of sediment impacts on freshwater and marine ecosystems, and how we might manage those impacts"*

The interest in fine sediment was primarily driven by the perception that the decline in trout numbers in the river in the mid-1990s (Fig. 1) was related to sediment impacts, with the finger pointed at forestry operations as the source of this sediment. There were also concerns related to mortality of scallops in areas of Tasman Bay near the Motueka River mouth.

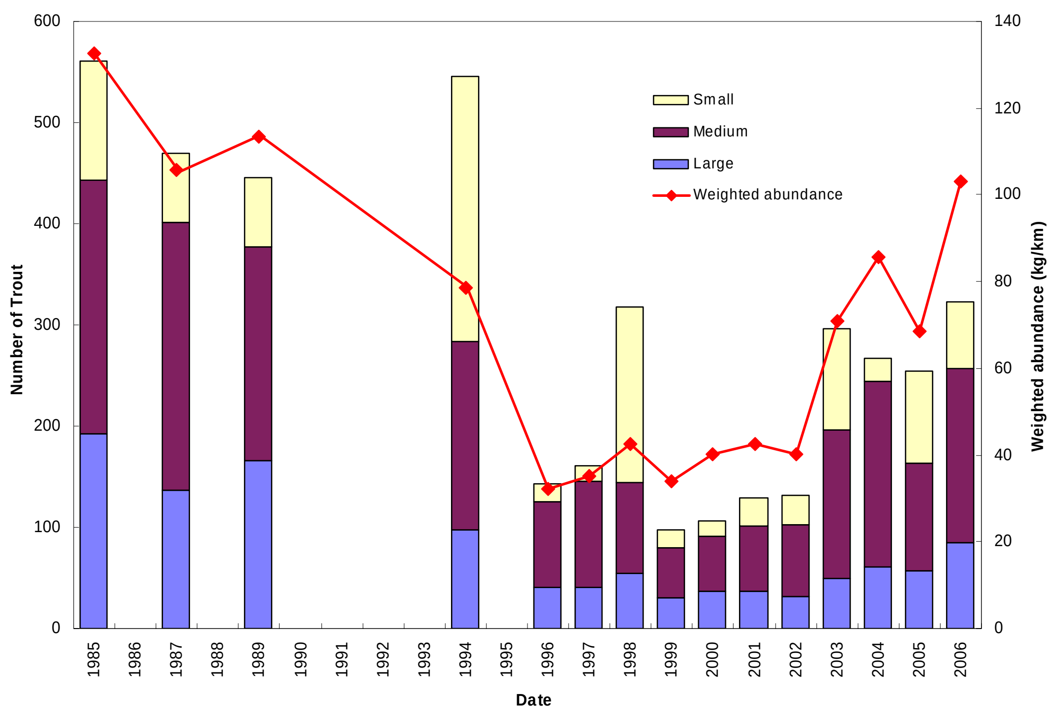

Figure 1 Trends in trout population in the Motueka River measured by drift dives at Woodstock 1985-2006

To reach this goal research was needed in the following areas:

- Identify sediment sources, loads and transport in different parts of the catchment
- Determine how changes in sediment loads and storage influence river morphology and habitat quality

- Investigate the links between sediment loads and ecological impacts in the river and bay
- Establish the impact of gravel extraction on riverbed levels
- Review the management options that can be used to limit sediment generation, movement and delivery to waterways.

This document summarises the progress that has been made towards this goal and suggests areas where our understanding is still lacking. An important aim of this document is to better understand how we might integrate the biology, hydrology and sediment strands of our research over the next (at least) 3 years.

What have we done so far

- Reviewed existing data/information sources on erosion and sediment in the Motueka Catchment (Basher and Hicks, 2003).
- Reviewed the literature on the effects of fine sediment on river biota (Crowe & Hay 2004).
- Produced a preliminary report identifying sediment sources in the Motueka River (Basher et al, 2003).
- Established a suspended sediment monitoring network and produced annual data reports (Hicks and Merrilees, 2003; Wild et al, 2004; Wild et al, 2006). This now includes the Motueka at Woodmans Bend (gives suspended sediment delivery to Tasman Bay), Motupiko at Christies (gives suspended sediment generation from hilly, low rainfall, Moutere gravel terrain), Wangapeka at Walters Peak (gives suspended sediment generation from steep, mountainous, high rainfall, western tributaries) and Motueka at Gorge (gives suspended sediment generation from steep, mountainous, high rainfall, headwater tributaries).
- Analysed all the historic river cross section data for the upper and lower Motueka (Sriboonlue and Basher, 2003; Ball, 2004).
- Produced posters for the ICM AGM on "What do we know about the impacts of sediment on trout", "A review of the effects of fine sediment on river biota" and "How do we characterise fine sediment abundance in the Motueka River?"
- In conjunction with Fish & Game, established and counted trout abundance in 10 randomly selected sites in the Motueka River downstream of the Wangapeka River confluence using annual drift dives. Some other sites (Motueka at Golden Downs, Glen Rae, Gorge; Motupiko at Korere; Pearse River; Wangapeka at Chummies Creek and Walters Peak; Riwaka at Moss Bush and Dehra Doon) are also monitored on a less regular basis.
- Sampled stream invertebrate density and community composition once at 46 sites throughout the Catchment (Shearer & Young 2004).
- Reviewed the literature on sediment measurement techniques and decided on a semi-quantitative method for assessing the composition of riverbed substrate (Basher & Phillips 2005).
- Established a network of approximately 28 sites where sediment composition in the riverbed will be characterised annually using the above method. The sites were chosen to coincide with drift dive reaches and other sites where biological or

water quality monitoring has been undertaken. 2 sites were also surveyed after the Good Friday flood in 2005.

- Investigated the effects of a near-bottom high turbidity layer on scallop feeding in Tasman Bay.
- Compared the biota present on coarse and fine substrates in the Motueka Delta and offshore plume regions with reference sites in other parts of Tasman Bay.
- Identified the ultramafic geology of the Red Hills as a natural source of elevated nickel and chromium containing sediments delivered to the mainstem of the Motueka River and Tasman Bay. An Otago University Masters student is currently investigating the biological effects of this material in the Bay.
- Produced model simulations and theoretical spatial patterns of suspended sediment deposition in Tasman and Golden Bay under contrasting river flow and wind direction scenarios (Tuckey et al. 2006)
- Established a long-term in situ data collection facility in the Motueka River plume of Tasman Bay. Turbidity data are continuously recorded at two depths.
- Identified a variety of physical, chemical and biological indicators of sediment related terrestrial influences on seabed habitats in Tasman Bay.

Ongoing work related to sediment includes:

- Measurement of suspended sediment concentrations at Woodmans Bend, Motupiko at Christies, Wangapeka at Walters Peak and Motueka at Gorge continue to be undertaken under subcontract by NIWA. This work provides some information on sediment particle size but does not include the wash load/sand component. This data is all at large catchment scale. We also have access to data at smaller catchment scale (both existing and ongoing) from 3 west bank tributaries (Herring, Big and Little Pokororo) via Tony Hewitt. This is the highest quality data we are collecting and we will continue to support as much as we can for the next 3 years, although we will have to progressively reduce the effort in data collection to allow for analysis and publication of this data.
- Further work on sediment source identification is underway using the 2000 orthophotos and field survey of bank erosion. This will provide a picture of the main erosion types and the distribution of sediment sources (landslides, gullies, debris flow, bank erosion, sheet erosion), and their relationship with land use/vegetation cover. It still needs to be turned into a quantitative measure of contribution to sediment load by looking at historic photos, or other techniques. This work doesn't currently incorporate the short-term impact of forestry very well.
- Bed sediment composition will be assessed on an annual basis at the 28 sites. Surveys will also be conducted at a subset of these sites after large floods to identify causes of change.
- Drift dive surveys have been conducted annually at the 10 randomly chosen sites in the main stem since 2002 (Fig. 1). Fish & Game are considering whether to continue investing this level of effort in future years. However, it is really important that this continues into the future since this provides the main long term biological dataset to compare with the bed sediment composition data.

- TDC monitors invertebrate community composition annually at 17 sites throughout the catchment as part of its State of the Environment monitoring programme. This data could provide useful linkage with any annual changes in sediment composition at these sites, although this data is restricted to community composition and not invertebrate densities.
- TDC also monitors water clarity and turbidity on a quarterly basis at their SoE sites, which gives a broader, but less precise picture, of likely sediment loads from different parts of the catchment (Young et al. 2005).
- Collection of midwater and near-bottom turbidity data will continue as one component of a buoy-mounted, long-term data collection facility in Tasman Bay. Baseline benthic ecological characterisitics at the buoy site have been surveyed by TDC for ongoing SoE monitoring.
- Repeated 2-D surveys of riverbed levels are being undertaken in a section of the Motueka above Tapawera to better understand the spatial pattern of riverbed aggradation and degradation. This will be an interesting comparison with the results from the cross-section surveys.
- River health has also been measured at 10 sites throughout the catchment using indicators of ecosystem function (functional indicators). This has involved measurements of primary production rates, ecosystem respiration rates and organic matter decomposition rates. Comparisons have been made with traditional measures of river ecosystem health that focus on invertebrate community composition (*e.g.* MCI scores) (Young et al. 2006). Further comparisons with bed sediment composition could also be made.
- Motueka iwi are also establishing a set of sites throughout the catchment where they will monitor ecosystem and cultural health.

Where is our understanding still limited?

- Flux of sediment from different sources. How much sediment comes from bank erosion, landslides, gullies, surface wash, etc, and how much comes from the DoC estate as opposed to the managed estate. Our suspended sediment data will broadly address the spatial patterns of sediment generation. The process understanding needs to come from techniques such as historic air photo analysis, direct measurement or sediment tracing techniques. We have a capability fund project on sediment tracing starting this year at Raglan and if this is successful it could be applied to the Motueka.
- Slugs of fine sediment - where do they come from, how fast do they move?. Most people focus on slugs of sand coming from Separation Point Granite, but there is a slug of fine sediment currently moving through the upper Motueka from the Good Friday 2005 flood. Our sediment characterisation sites should allow us to track new slugs of sand and we plan to use the local knowledge of long-term fishermen to piece together evidence on past slugs of fine sediment
- Placing forestry impacts in perspective. We’re currently not doing any specific work on forestry-related erosion but need to be able to deal with its impacts because it’s the primary land use that is regulated for sediment control, and much of it is on erosion-prone land (both Separation Point granite and Moutere gravel).

We have some small catchment data, and we have Tony Hewitt's west bank data but we still struggle to know at the large catchment scale really how important forestry is compared to other sediment sources.

- Relating sediment to biological impacts at catchment scale. At the reach scale, and at the national scale, there is convincing evidence of the importance of fine sediment in influencing trout numbers. However, one of the unanswered questions is the extent to which trout numbers in a specific reach are affected by a particular slug of sand that is transient in the reach. It may be that although a particular reach has a large amount of sand, the overall trout population has been enhanced by better conditions elsewhere in the river and therefore the particular site also has elevated trout numbers compared to what might have been expected. Obviously trout are able to move around relatively easily. The effect on invertebrate density or composition (trout food), or maybe periphyton, may be more marked at a particular site due to elevated sand levels as they are less mobile. Alternatively this might not be the issue we thought it was.
- Modelling sediment dynamics and linking sediment dynamics with biological impacts. We've made slow progress on developing an erosion/sediment model that effectively simulates spatial patterns of sediment generation and dispersal, and allows us to evaluate management options. We've made even less progress in being able to link this with a biological impacts model. A PhD student at Otago is trying to use the CAESAR model to simulate sediment generation and transport, and morphological development of part of the Motueka River. Ian Fuller's PhD student will probably incorporate a modelling component in her PhD topic. Murray Hicks has a post-doc just starting work on developing a model to simulate the effect of changing flow patterns and sediment load on river bed morphology and sediment composition (and ultimately on habitat conditions). It is likely that he will do some of this work in the Motueka.
- Little or no effort has gone into an assessment of mitigation options for sediment. Forestry companies operate under various industry practice standards, some of which involve management actions to reduce sediment generation, movement and delivery to waterways. Many of these methods are well developed and tested experientially. However, due to pressure that is being exerted on forestry companies they are interested in having an external agency assess the relative effectiveness of different sediment control options and providing more quantitative measures of performance.
- The toxicity of nickel and chromium laden sediment within the river is currently unknown, although invertebrate sampling in the Red Hills has indicated a very low diversity of invertebrates in this area. The toxicity work underway in Tasman Bay by Reid Forrest (Otago MSc student) may also provide guidance on the potential significance of this issue in freshwaters.

The way forward

There are still lots of questions that we are unable to answer. The aim of this document is to identify potential strands of research that could fill information gaps and prioritise which ones can be tackled over the next 3 years.

Option A)

One potential strand of work is linked with sediment issues, but also relates to low flows and turbidity. This work would involve the development of a catchment scale model that uses bioenergetic concepts to predict relative trout growth in different parts of the catchment and thus identify motives for fish movement around the catchment. This model would incorporate the three key elements affecting trout growth – habitat, temperature and food availability. The habitat component would have two parts – one relating to the effects of flow variation (low flows) and the other measuring habitat quality. This latter habitat quality component is linked with sediment loads/storage and would involve measurements of channel geomorphology, specifically thalweg profiles that map the abundance, length and depth of pools and the variability of profile. Measurement of these habitat metrics has been shown to be repeatable, independent of flow conditions and recent studies have indicated close correlations between these metrics and salmonid abundance (Mossop & Bradford 2006)). We anticipate taking annual measurements of these metrics at representative sites throughout the catchment in conjunction with bed sediment composition measures. Electric fishing and/or drift dives would be used to collect information on fish abundance to relate with these metrics. The food supply component also has potential linkages with sediment composition via effects on invertebrate communities and also via change in water clarity and thus feeding efficiency. We anticipate using existing information on invertebrate community density and composition, along with water clarity data to populate the model. However, further sampling of benthic invertebrate communities and perhaps also drifting invertebrate densities may also be required for the model.

Option B)

The drift dives provide a rare example of a long term dataset on changes in fish abundance. It could be fruitful to spend some effort trying to relate spatial and temporal changes in fish abundance with potential controlling factors. These controlling factors could be related to sediment composition and effects on habitat quality, or a variety of other factors not necessarily associated with sediment (e.g. floods, droughts, shags, fishing pressure, food supply). See Appendix 1 for further discussion on this.

Option C)

Detailed work relating bed sediment composition with invertebrate densities and community composition could also be conducted. This could be carried out using either a descriptive approach comparing different sites within the catchment where we know there are differences in the bed sediment composition, or an experimental approach in the field or laboratory where sediment is added and the effects observed. This work would be very resource hungry and in our opinion may not advance understanding beyond that reviewed previously (Crowe and Hay 2004).

Option D)

There is a stronger rationale for focussing on comparisons among the effects of fine Moutere clays, fine ultramafic sediments, and coarse Separation Point granite sands on invertebrate communities. Other possible questions relate to the effects of fine sediment on flow exchange and invertebrate communities living beneath the streambed. Often little sediment may be observed at the surface of the riverbed, but abundant amounts beneath the surface may clog up spaces among the rocks affecting habitat availability and quality. Once again, however, any research attempting to characterise sediment and communities below the riverbed surface is very resource hungry.

Option E)

In Tasman Bay a key question related to the near-bottom turbidity layer is the relative importance of riverine sediment inputs versus natural and dredge-induced resuspension of sediment from the bottom of the bay. A better understanding is required of current velocity thresholds for sediment re-suspension.
The continuous measurements from Woodmans Bend and from the monitoring buoy provide information that could be used for this purpose. More work is required to determine the spatial extent and effects of river sediment inflows to Tasman Bay and temporal relationships (e.g. storm events, seasons). Theses would enable a better understanding of the implications for fish and shellfish resources.

Option F)

Linking sediment sources and fluxes from these sources. This needs to be done if we decide that we need to better manage sediment inputs into the river and bay. However it will be very resource hungry because of the size of the catchment, the diversity of contributing processes, and the style of contribution (our current knowledge would suggest small contributions from a very large number of individual sources, rather than a large contribution from a few sources).

Option G)

Sediment transport and biological impacts modelling. Linking bed sediment composition monitoring, identification of slugs of sediment, habitat distribution and quality, with biological productivity. This is probably the most challenging, but potentially most rewarding, approach. It would also be transferable beyond the Motueka. The IDEAS work, application of CAESAR, and Murray's post-doc are starting down this route. There is also considerable potential for linking the sediment load calculations with the modelling efforts in Tasman Bay which is an integral part of IDEAS.

Option H)

Ecological impacts of gravel extraction. There is some interest in other parts of the country and NIWA has done some preliminary work on 2 sites (Kakanui & Waimea). However, in theory the effects should be restricted to relatively small areas and (in principle at least) is limited by rules limiting extraction from wetted parts of the river.

Option I)

Linkages between bed level change and aquifer recharge. This issue has been addressed to some extent. However, limited information on historical abstraction rates from the aquifer means that it is impossible to separate the effects of abstraction from the effects of a lower riverbed.

Option J)

Bedload sampling could be undertaken, but this would be very resource hungry and we would have to justify a need for this work.

Option L

There is also some potential for using characteristics of vertical profiles of Tasman Bay sediment cores to investigate historical sedimentation patterns.

Recommendations

At this stage we recommend proceeding with Options A, B, E, F, and G, but are looking forward to receiving feedback from the Sediment Learning Group on the options and priorities.

An important point that needs to be addressed immediately is to encourage Fish & Game to continue with the drift dives in the 10 randomly chosen sites along the mainstem of the Motueka River.

References

Ball, L.G.A. 2004: Quantifying the morphological effects of gravel extraction on the Motueka River. M.Appl. Sci. thesis, Lincoln University.

Basher, L.R., Hicks, D.M. 2003: Review of existing data on erosion rates and sediment yield for the Motueka catchment. ICM Report 2002-03/02, Landcare Research, Lincoln.

Basher, L.R., Marden, M., Barringer, J., North, H. 2003: Identification of major sediment sources in the Motueka River. ICM Report 2002-03/01, Landcare Research, Lincoln.

Crowe, A., Hay, J. 2004: Effects of fine sediment on river biota. Cawthron Report No. 951.

Hicks, D.M., Merrilees, R. 2003: Suspended sediment monitoring in the Motueka catchment: data report to 30 June 2003. NIWA Client Report CHC2003-078, NIWA, Christchurch.

Mossop, B., Bradford, M.J. 2006: Using thalweg profiling to assess and monitor juvenile salmon (*Oncorhynchus* spp.) habitat in small streams. Canadian Journal of Fisheries and Aquatic Sciences 63: 1515-1525.

Phillips, C.; Basher, L. 2005: Catchment channel characteristics and riverbed substrate assessment – a review and trial of a method of fine sediment assessment in the Motueka River. ICM Report 2004-05/01.

Sriboonlue, S. Basher, L.R. 2003: Trends in bed level and gravel storage in the Motueka River 1957–2001: a progress report on results from analysis of river cross section

data from the upper and lower Motueka River. ICM Report 2002-03/04, Landcare Research, Lincoln.
Shearer, K.A.; Young, R.G. 2004: Interacting influences of geology and land use on macroinvertebrate communities. Unpublished Cawthron Report.
Tuckey, B.J.; Gibbs, M.T.; Knight, B.R.; Gillespie, P.A. 2006: Tidal circulation in Tasman and Golden Bay: implications for river plume behaviour. New Zealand Journal of Marine and Freshwater Research 40: 305-324.
Wild, M., Hicks, D.M., Merrilees, R. 2004: Suspended sediment monitoring in the Motueka catchment: data report to 30 June 2004. NIWA Client Report CHC2004-118, NIWA, Christchurch.
Wild, M., Hicks, D.M., Merrilees, R. 2004: Suspended sediment monitoring in the Motueka catchment: data report to 30 June 2004. NIWA Client Report CHC2004-118, NIWA, Christchurch.
Wild, M., Hicks, D.M., Merrilees, R. 2006: Suspended sediment monitoring in the Motueka catchment: data report to 1 May 2006. NIWA Client Report CHC2006-087, NIWA, Christchurch.
Young, R. G.; Quarterman, A. J.; Eyles, R. F.; Smith, R. A.; Bowden, W. B 2005: Water quality and thermal regime of the Motueka River: influences of land cover, geology and position in the catchment. New Zealand Journal of Marine and Freshwater Research 39: 803-825.
Young, R.G.; Matthaei, C.D.; Townsend, C.R. 2006: Functional indicators of river ecosystem health – final project report. Prepared for Ministry for the Environment. Cawthron Report No. 1174. 38 pp.

Appendix 1 - Changes in trout abundance and potential controlling factors

Drift dives have been undertaken at Woodstock on the main stem since 1985. Trout numbers declined significantly between 1994 and 1996 (Figure 1). However, F&G wondered if this site is representative of changes in fish abundance throughout the catchment. As a result ten randomly chosen sites have been surveyed since 2002.

What this shows is

- at Woodstock there was a major decline in trout numbers and abundance/biomass between 1994 and 1996 (there is a suggestion that this also occurred at other sites, although the timing and severity of decline may not be so marked). Numbers and abundance/biomass remained low for 7 years but has recovered substantially since 2003.
- During most years the annual changes in trout abundance at the Woodstock site reflect the annual changes in other sites. However, the 2006 data were extremely variable with highest ever abundances recorded at some sites and lowest ever abundances recorded at other sites (Figure 2).
- Data from 2003, 2004 and 2006 showed a general trend towards downstream increases in trout abundance, although counts at the lower 2-3 sites in 2004 and 2006 were low and potentially affected by poor water clarity (Figure 2). No clear patterns in trout abundance were seen in 2002 and 2005 (Figure 2). See also Figures 3-7 for results for each year and Figure 8 for changes in biomass over time.

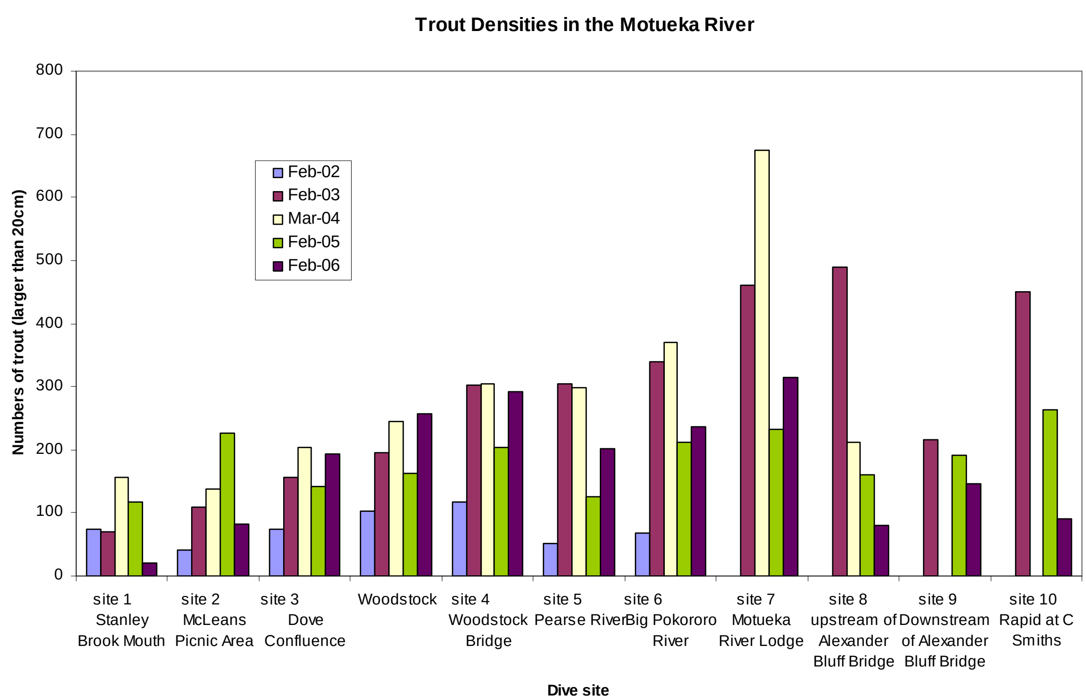

Figure 2 Annual changes in large and medium trout abundance at sites along the main stem of the Motueka River from 2002 – 2006.

We had a flurry of discussion on the Land-Water-Marine online discussion group after Roger summarised the results of the 2004 drift dive – this is summarised here to refresh our memories and to reflect on whether we have advanced our understanding of the biological impacts of sediment since then. It began on 3 May 2004 with Roger posting the results of the latest drift dive results showing that:

- trout numbers were continuing to increase at Woodstock
- observing that the key trend shown in the 10 drift dive sites in the main stem is a downstream increase in trout numbers and that the reasons for that are not entirely clear (bigger river, better habitat and food availability, temperature effects).

Tim asked questions about the accuracy of the drift dive method and about what flood characteristics might influence temporal trends. There was further discussion about drift diving clarifying its usefulness and limitations, which suggested that while drift diving does have some limitations the spatial and temporal trends we are seeing in the data are likely to be real. The conversation continued on the flood question with Neil

- observing that the 1995 upper Motueka flood (coincident with the decline in trout numbers at Woodstock) discolored the river for a long time and might have triggered the rapid decline, but found it difficult to explain the longer term reduction in fish numbers (i.e. he would have expected the population to recover within 3 yrs)
- suggesting it was unclear what flood characteristics were important (timing, magnitude, location).

Tim provided results of flood analysis for Motupiko, Gorge, Wangapeka, and Woodstock using criteria of ARI=4 years and between August and November (criteria derived from the Kakanui study) and observed that hydrologically the 2 floods that stood out were in August 1990 and October 1998 (which doesn't coincide with the trout decline between 1994 and 1996 drift dives). There was some further discussion about the role floods might play, including the need to consider all floods and not just those in the spawning period (Aug-Nov) - certainly some of the largest and arguably most significant floods occurred outside this period as Martin and Neil noted for the upper Motueka flood of Feb 1995 (this would also apply for the recent large March 2005 flood).

Les widened the discussion with some comments on the influence of sediment on trout numbers, noting in particular that the results from the 2004 drift dive survey (Fig. 5) showed little relationship between elevated levels of fine sediment (seen in reach 5) and trout numbers. He expressed the view that - we could invest a lot of time and effort into the 10 main stem reaches without gaining the understanding of the influence of bed composition on trout populations that we need - its hard to see us being able to quantitatively survey all 10 reaches each time a drift dive survey is done, so perhaps we need to be a bit more strategic. He suggested that tracking the big slugs of sediment might be a useful first step.

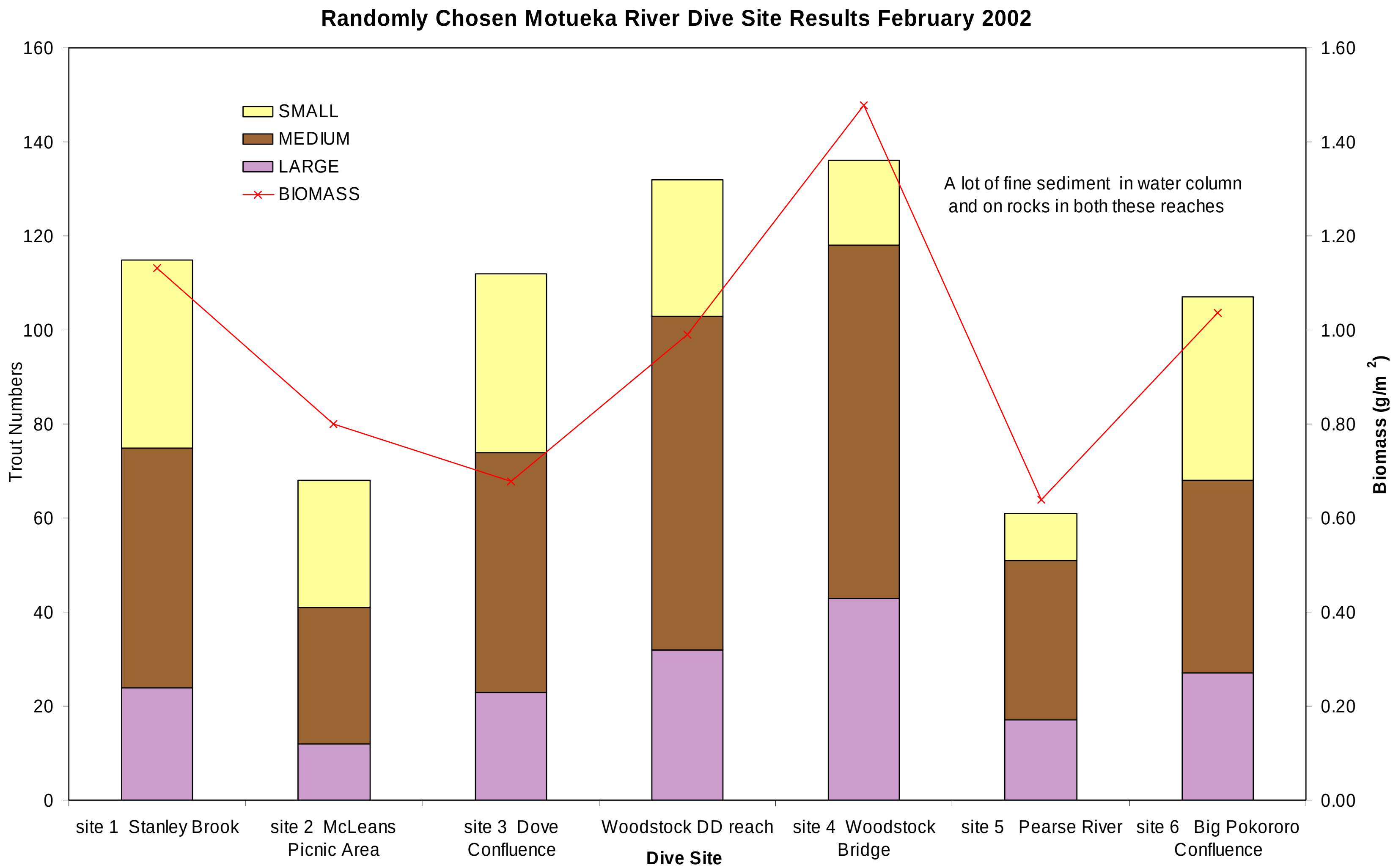

Figure 3 Trout numbers and biomass at randomly chosen sites in the Motueka River main stem, 2002

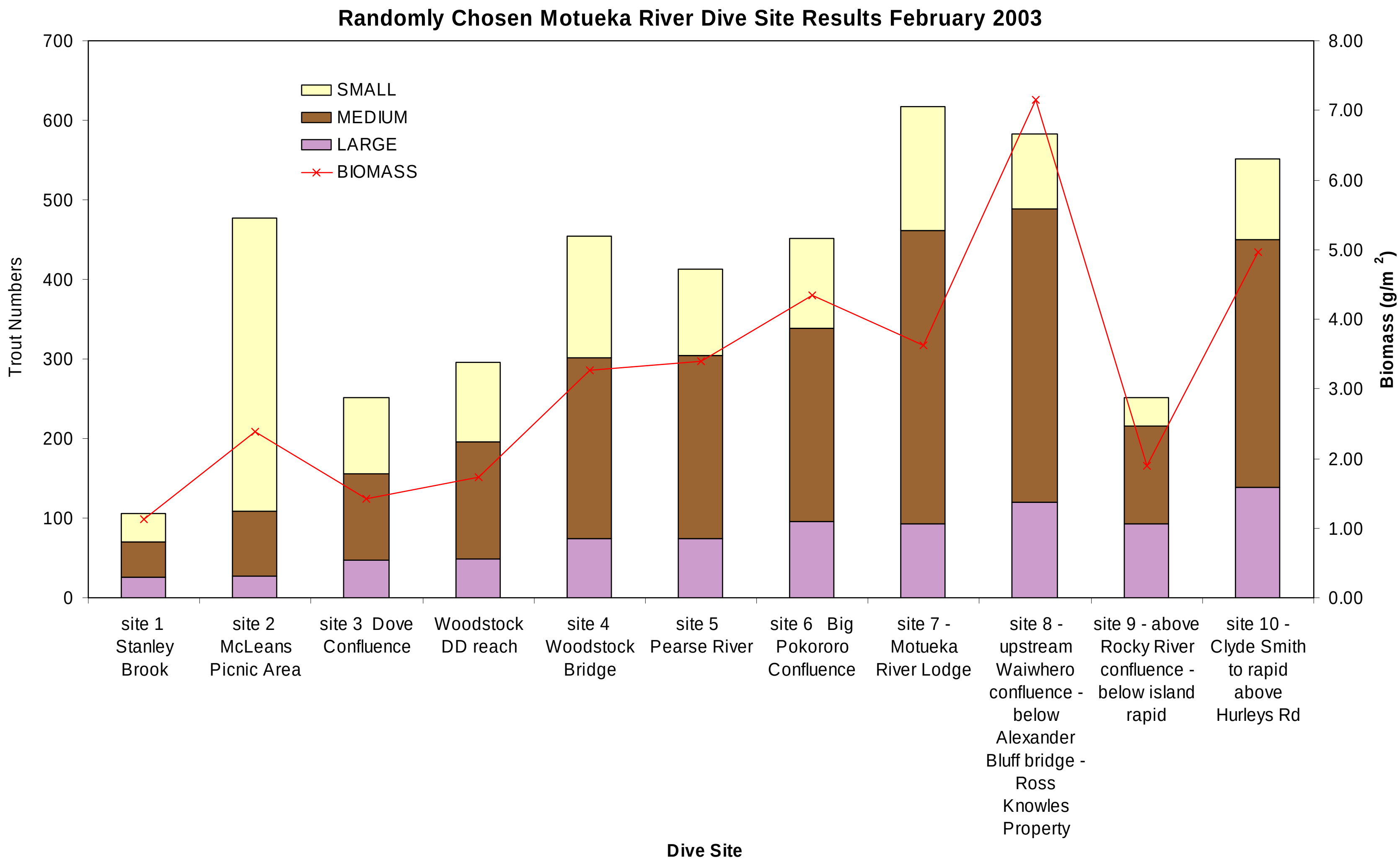

Figure 4 Trout numbers and biomass at randomly chosen sites in the Motueka River main stem, 2003

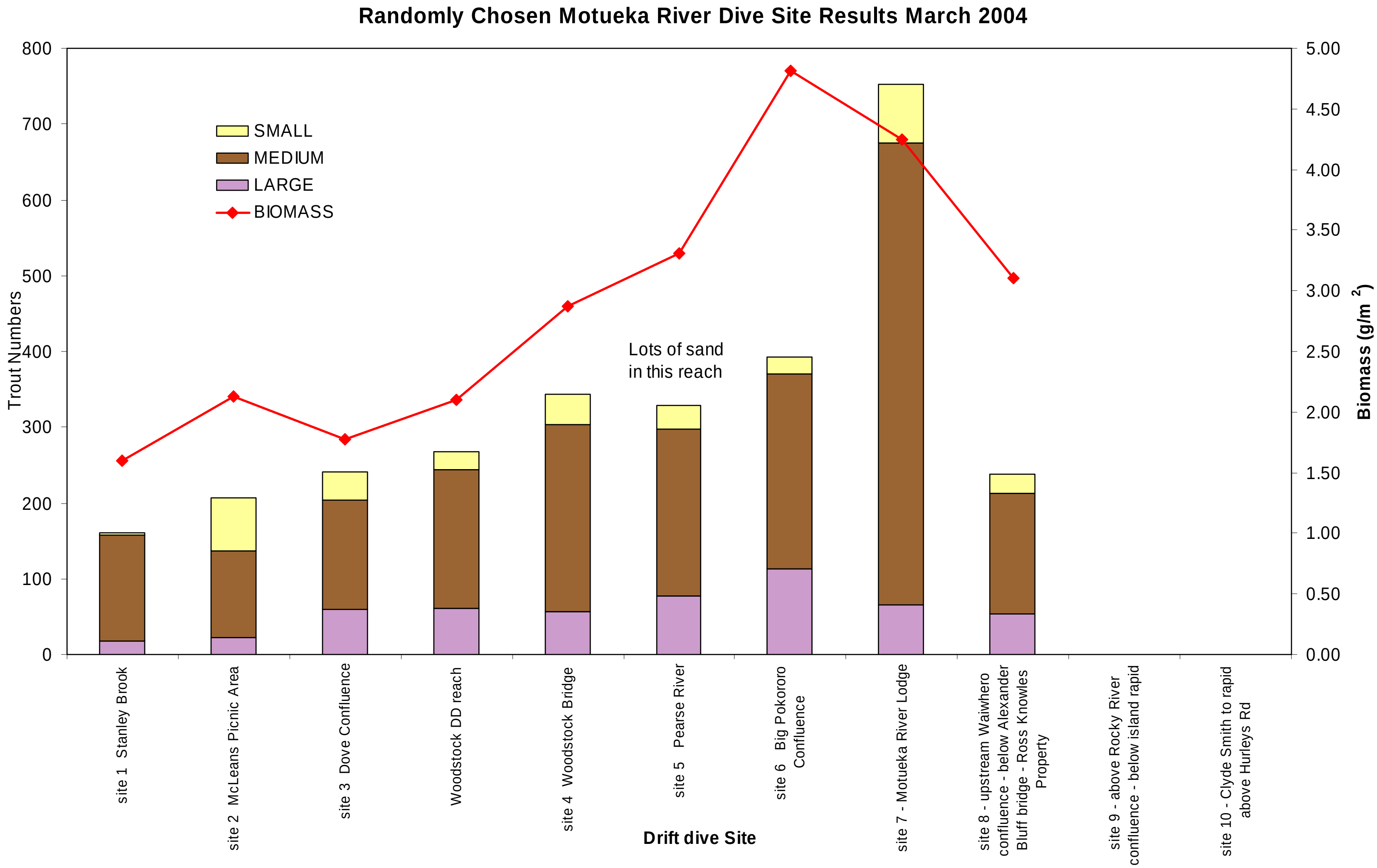

Figure 5 Trout numbers and biomass at randomly chosen sites in the Motueka River main stem, 2004

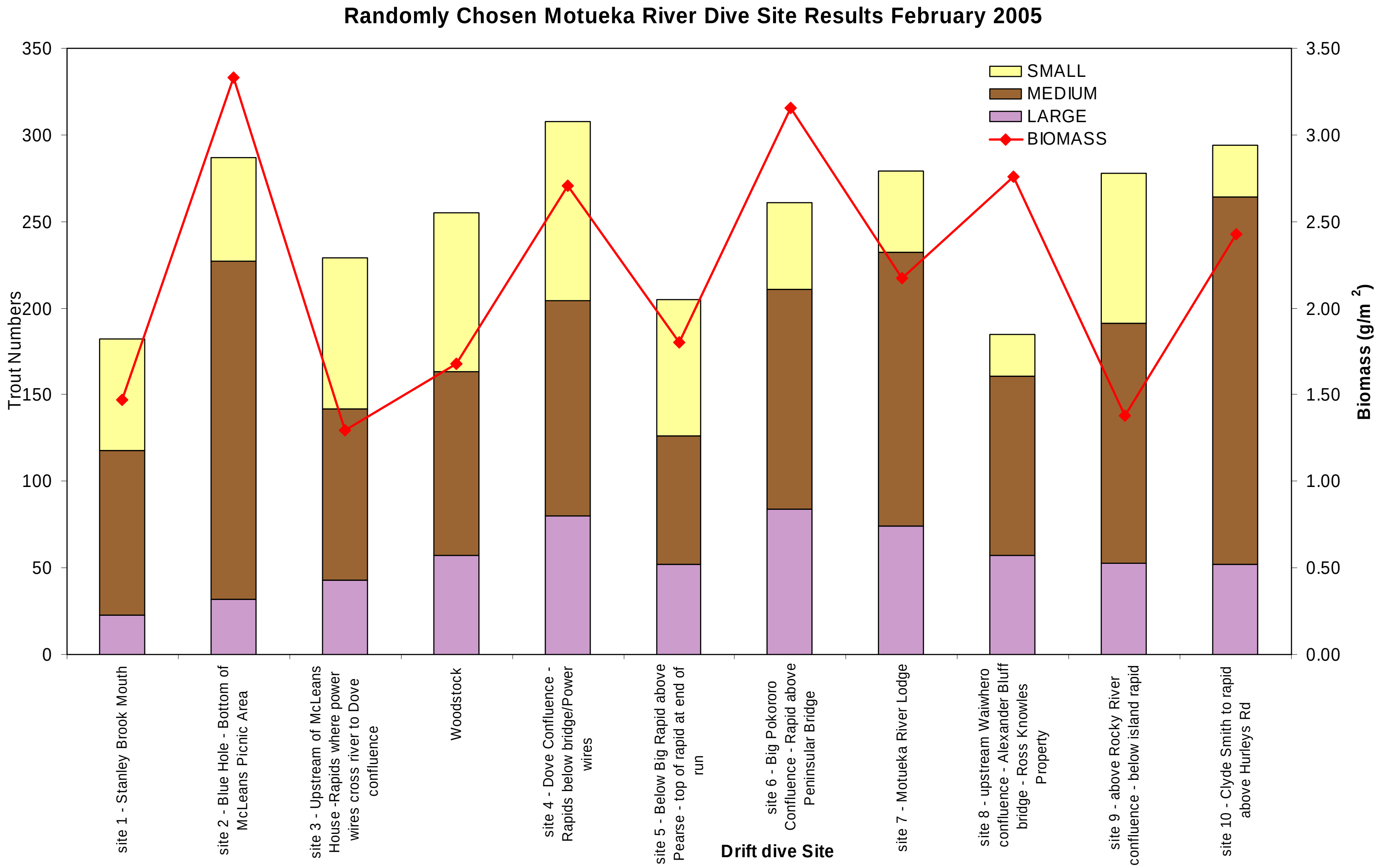

Figure 6 Trout numbers and biomass at randomly chosen sites in the Motueka River main stem, 2005

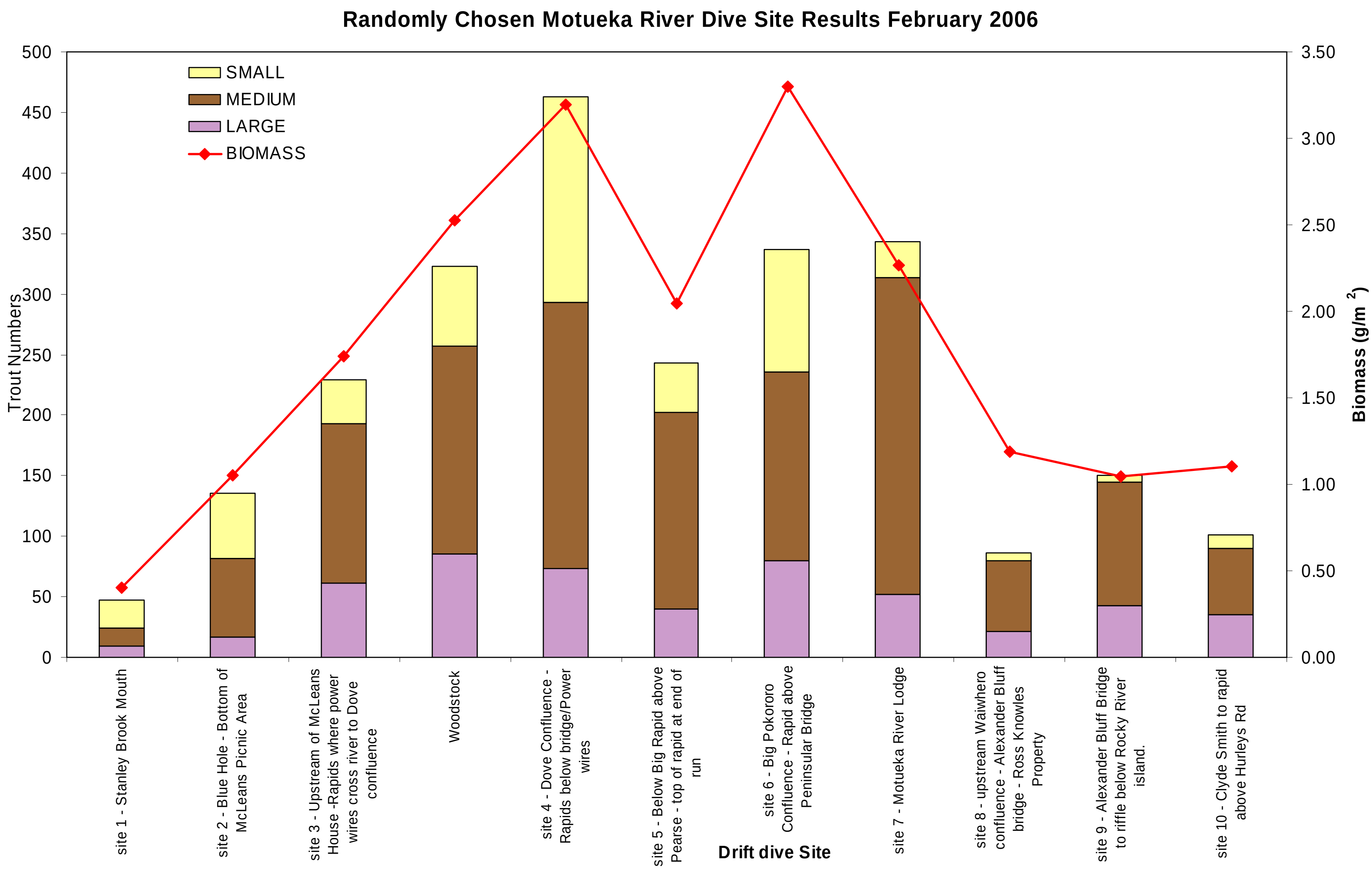

Figure 7 Trout numbers and biomass at randomly chosen sites in the Motueka River main stem, 2006

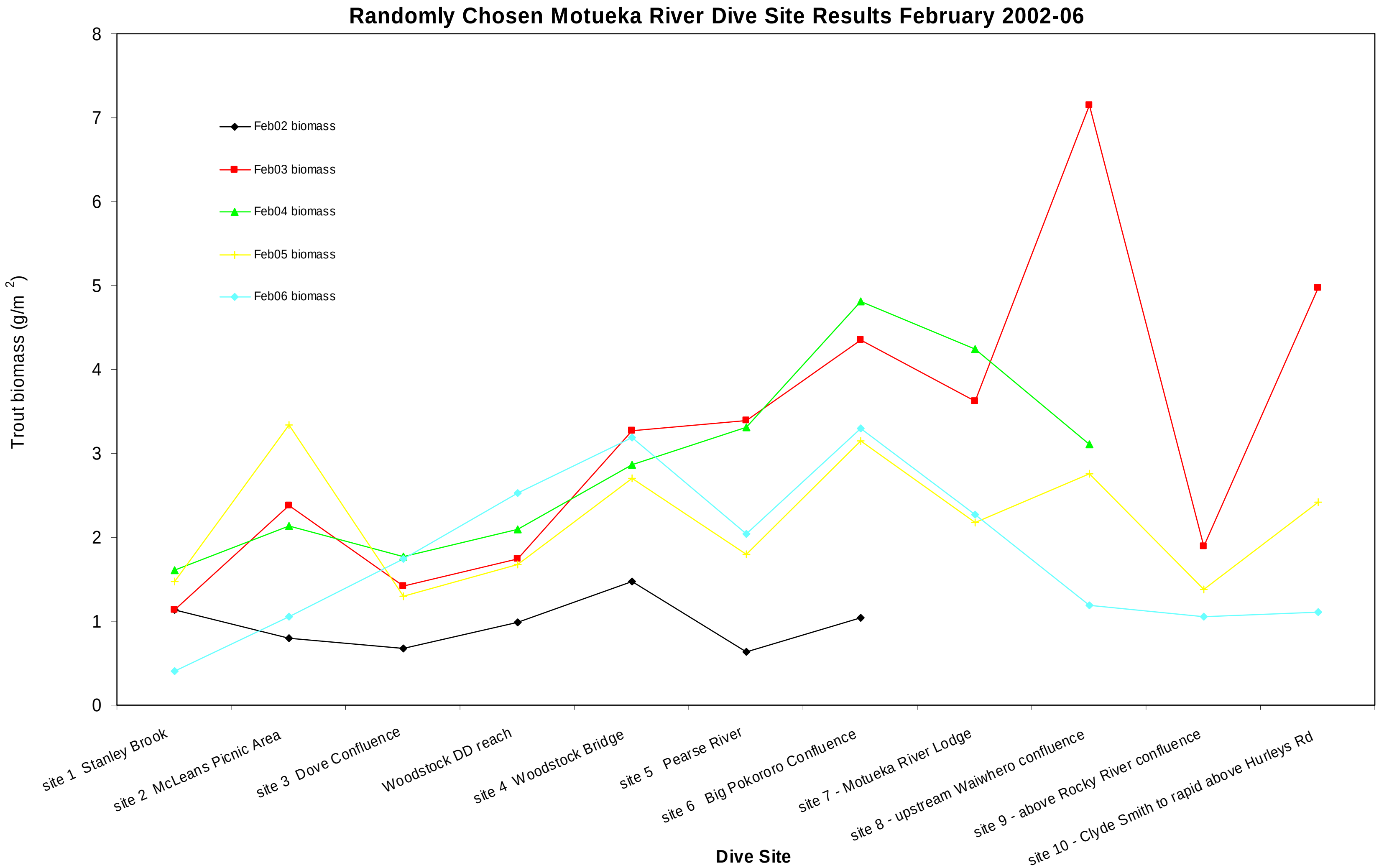

Figure 8 Trends in trout biomass at randomly chosen sites in the Motueka River main stem, 2002-06