CAWTHRON

Nutrient Loading from the Motueka River into Tasman Bay, 2007

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Nutrient Loading from the Motueka River into Tasman Bay, 2007

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PREFACE

An ongoing report series, covering coastal-sea components of the Motueka Integrated Catchment Management (ICM) Programme, has been initiated in order to present preliminary research findings directly to key stakeholders. The intention is that the data, with brief interpretation, can be used by coastal managers, environmental groups and users of coastal marine resources to address specific questions that may require urgent attention or may fall outside the scope of ICM research objectives. We anticipate that providing access to marine environmental data will foster a collaborative problem-solving approach through the sharing of both ICM and privately collected information. Where appropriate, the information will also be presented to stakeholders through follow-up meetings designed to encourage feedback, discussion and coordination of research objectives.

EXECUTIVE SUMMARY

The information provided in this report was collected as part of a collaborative research effort called the Motueka Integrated Catchment Management (ICM) programme. The programme was designed to assess the effects of various land use practices on terrestrial, freshwater and marine ecosystems in a "*ridge tops to the sea*" approach. One component of a Cawthron investigation into the effects of freshwater inflow quantity and quality on the productivity of the marine receiving environment is presented here.

The aim of this investigation was to estimate the rate of discharge of several dissolved and particulate nutrients into Tasman Bay, via the Motueka River, during the 2007 calendar year. In order to accomplish this, it was first necessary to develop flow/concentration relationships using various data sets assembled from historical river flow and water quality information (Gillespie *et al*. 2006).

Flow/concentration relationships were assessed for different river states (steady, rising and receding flows) and seasons (summer, winter). In general, highest estimated nutrient concentrations were associated with rising flood flows, particularly during winter months. However, high concentrations of a number of nutrient species were also estimated to have occurred during October and January.

The estimated mass transport of nutrients into Tasman Bay via the Motueka River during the 2007 calendar year was:

	Average flow (m^3/s)	TN (t)	NO_3(t)	NH_4 (t)	DIN (t)	DRP (t)	TP (t)	DRSi (t)
2007	55.7	295	182	10	192	6	28	11310

Relatively high discharges for most nutrient species were indicated for the winter months of May-August, and the greatest discharges (more than twice the next highest month) were indicated for October when several large flood events occurred in the catchment.

The flow/concentration relationships described here and the resulting 2007 loading estimates are considered to be generally representative of the Motueka River under the present catchment land usage. At these discharge rates, the nutrients delivered into the Bay would likely contribute to coastal production in a beneficial way with little potential for dysfunctional ecosystem enrichment effects. The observed variations in monthly delivery patterns would be expected to affect phytoplankton production rates and seasonal cycles with possible follow-on implications for shellfish resources in Tasman Bay.

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1. INTRODUCTION

1.1. Background

The information provided in this report has been collated and interpreted as part of a collaborative research effort called the Motueka Integrated Catchment Management (ICM) programme. For a description of the programme structure and rationale, refer to Basher (2003). The programme was designed to assess the effects of various land use practices on terrestrial, freshwater and marine ecosystems in a "*ridge tops to the sea*" approach.

This report follows on from a previous report evaluating flow/concentration relationships for several dissolved and particulate nutrients in the Motueka River and their estimated discharge rates into Tasman Bay during 2005 and 2006 (Clark *et al*. 2007). The present report uses the same flow/concentration relationships to estimate the discharge rates of nutrients during 2007. The nutrients evaluated were total phosphorus (TP), dissolved reactive phosphorus (DRP), total nitrogen (TN), ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N) and dissolved reactive silica (DRSi). Estimated average daily concentrations and load estimates are reported for each month in the 2007 calendar year. These data enable ongoing evaluation of short- and medium-term (*e.g*. daily, monthly *etc.*) variation in nutrient discharge rates for investigation of their implications to the river plume ecosystem.

1.2. Study area

The Motueka River and its tributaries (Figure 1) drain a land catchment of ~2,180 km^2 comprised of approximately 35% native bush, 25% planted forest, 19% pasture and 12% scrub by area (Basher 2003). The river has a mean flow of 59 m^3/s and a measured flow range from about 5.6 m^3/s to greater than 2,100 m^3/s (Basher 2003). Flow is seasonally variable and is usually high in winter and spring and low in summer. The river is prone to large floods and extended periods of low flow. These temporal flow variations have a significant influence on nutrient concentrations and therefore it is important to consider them when assessing temporal mass transport patterns. References containing background and related research information describing the Motueka River catchment and the receiving water of Tasman Bay can be accessed through http://icm.landcareresearch.co.nz.

1.3. Why are nutrients important?

The Motueka River flows into Tasman Bay through an unconfined intertidal and shallow subtidal delta (Gillespie *et al*. 2004). Nutrients contained in the river water nourish delta plant communities (*e.g*. saltmarsh, eelgrass, macroalgae) and coastal phytoplankton productivity thereby contributing to fish and shellfish production within a large plume-affected region of the western Bay (Gillespie 2003; Mackenzie *et al*. 2003; Forrest *et al*. 2007). The size of the Motueka River outwelling plume varies considerably depending upon flow; however following a moderate rainfall event (*i.e.* in the order of 200 m^3s^{-1}) the plume can almost completely encompass three designated offshore aquaculture management areas (Figure 2). Excessive nutrient discharge can lead to accelerated eutrophication of coastal environments and adverse symptoms of over enrichment (*e.g.* problematic algal blooms, oxygen depletion, dysfunctional changes in biotic communities). Conversely, a significant reduction in nutrient discharge could lead to reductions in coastal primary productivity and subsequent diminishment of fish and shellfish resources. Ongoing information describing nutrient discharge rates is therefore required in order to develop a catchment strategy that will enable sustainable management of biological resources within Tasman Bay.

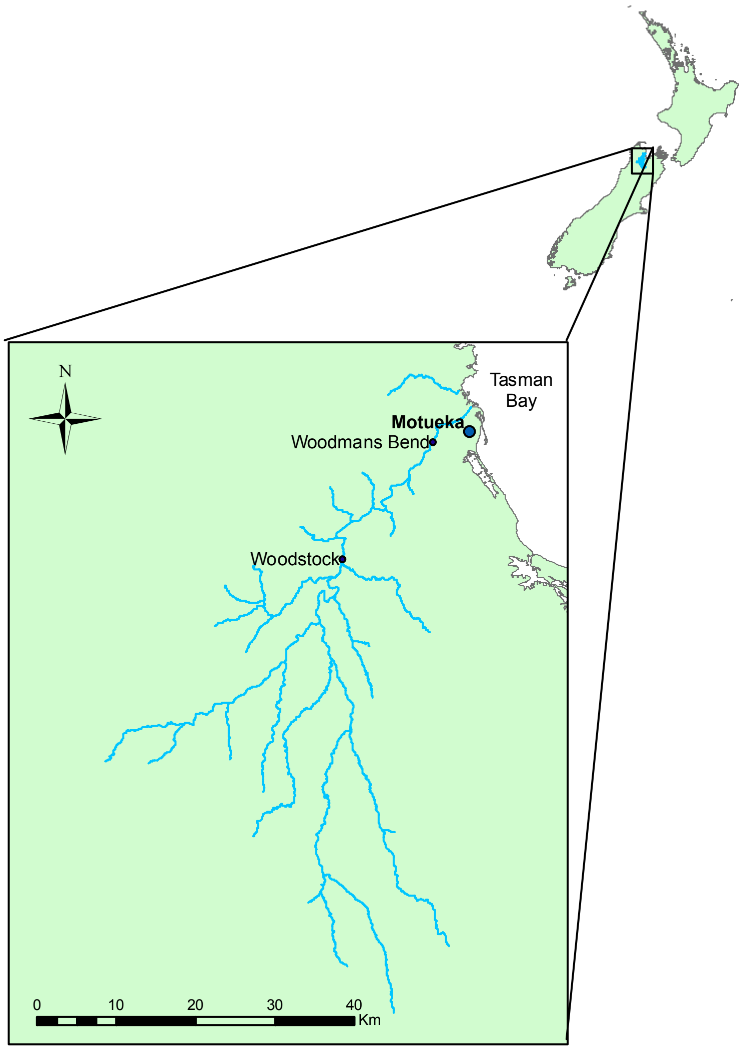

Figure 1. Location map of the Motueka catchment and data collection points.

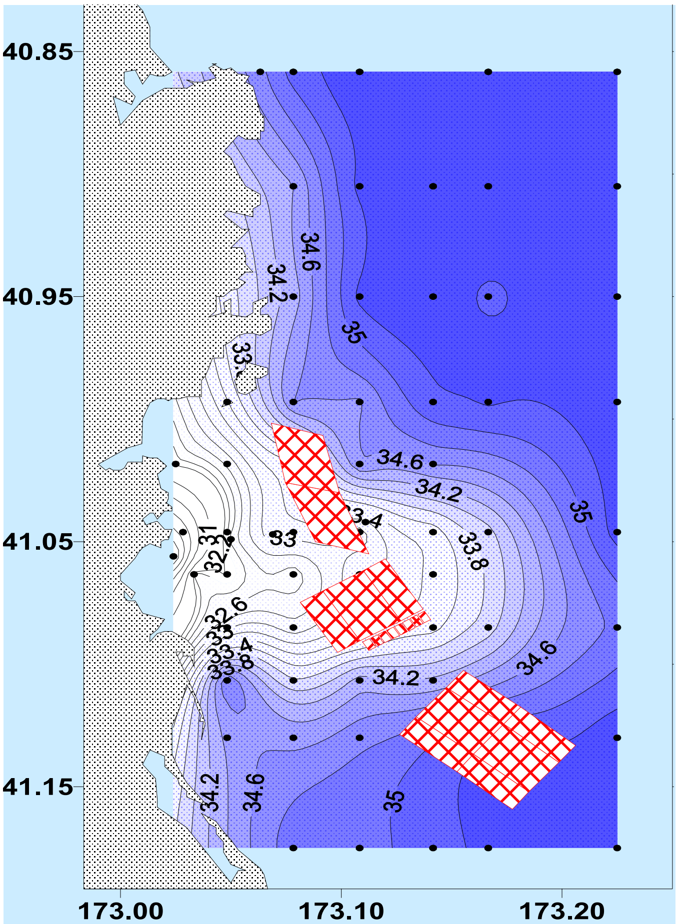

Figure 2. Spatial extent of the Motueka River outwelling plume (surface salinity field) after a moderate rainfall event with flows up to 200 $m^3 s^{-1}$ (from Tuckey *et al.* 2006).

2. METHODS

This report follows on from an original study looking at nutrient loadings in the Motueka River during 2005 (Gillespie *et al*. 2006). A more recent study (Clark *et al*. 2007) looking at the nutrient loadings in the same river for 2006, and reanalysing the loadings for 2005, adopted a new, more objective method for splitting the river flow data into rising, steady and falling components (see methods below). This new method represents an improvement in precision and repeatability from that used in the original study and continues to be used in this report. It is recommended that the updated values for 2005 reported by Clark *et al*. (2007) should replace those reported in Gillespie *et al.* (2006).

2.1. Calculations

Flow data was split into three flow states (rising, steady or receding) and two seasons (October-March) and (April-September). The flow states were defined as follows, where *x* is a 2 hour moving average of the difference between sequential flow readings (15 minutes apart) in the previous 2 hours;

Rising = $x \geq 0.25$ m^3/s

Steady = x >-0.05 m^3/s and <0.25 m^3/s

Receding = $x \leq -0.05$ m^3/s

The percentage of time that the river was in each category and the average flow while in that category was then used to generate the following equations to estimate monthly average concentrations and mass loadings for each nutrient. There was no flow/concentration relationship available for silica (see Gillespie *et al*. 2006 for explanation). Therefore mass transport calculations for this nutrient were based on average concentrations for flows <80 m^3s^{-1} and average concentrations >80 m^3s^{-1} and the corresponding loadings are rough approximations. The relationships for total nitrogen (TN) and nitrate (NO_3-N) under steady-state flows were limited to a maximum flow of 25 m^3/s. Therefore steady flows above 25 m^3/s were considered to be receding, as it was assumed that if the flow is high and steady the river is probably beginning to slowly recede after a flood event. These relationships may be able to be improved as further data becomes available.

Equation 1

Average concentration ($conc_{avg}$) (mg/L) = ($conc_{steady}$ x t_{steady})+ ($conc_{rise}$ x t_{rise}) + ($conc_{recede}$ x t_{recede})

Where t = time in state/unit of time (*e.g*. month) and conc = average concentration (mg/L) according to the equation determined from Table 1. The values used in the equation vary according to river state and season and the parameter being tested.

Table 1. Equation characteristics used to calculate average nutrient concentrations for the different data groupings.

Concentration (conc) = a x V_{flow} + c						
		Summer			**Winter**	
a	Steady	Rising	Receding	Steady	Rising	Receding
TN	0.000002	0.0000004	0.0000008	0.00001	0.000002	0.000001
NH_4-N	-0.00000009	-0.000000005	0.000000005	-0.0000001	0.000000004	0.000000005
NO_3-N	0.000002	0.00000001	0.00000002	0.00002	0.0000003	0.0000003
TP	0.0000007	0.0000005	0.0000004	0.0000001	0.0000007	0.0000004
DRP	0.00000004	0.000000004	0.00000002	0.0000001	0.00000001	0.000000004
		Summer			**Winter**	
c	Steady	Rising	Receding	Steady	Rising	Receding
TN	0.09	0.165	0.1425	-0.0423	0.2734	0.2507
NH_4-N	0.0075	0.0058	0.0055	0.0071	0.005	0.0048
NO_3-N	0.0214	0.0946	0.1026	-0.1491	0.1609	0.2062
TP	0.0045	0	0	0.0017	0	0
DRP	0.0011	0.0034	0.0026	0.0011	0.0097	0.0034

Equation 2

Mass Load (kg/day) = V_{flow} x $conc_{avg}$

Where V = volume of flow per day and $V_{flow} = (V_{steady} \times t_{steady}) + (V_{rise} \times t_{rise}) + (V_{recede} \times t_{recede})$

3. RESULTS

3.1. Average nutrient concentrations

The flow concentration relationships indicate that the highest nutrient concentrations were discharged into Tasman Bay during the winter months however the pattern varied amongst the various nutrients. For example, nitrate concentrations were highest in April–September, while total and dissolved phosphorus concentrations were highest in May–October (Figures 3 and 4). Highest concentrations were generally consistent with periods of higher flows (Figure 5), although the highest flow was seen in October but the nutrient concentrations for the same month were not the highest recorded. Of the summer months, October and January produced the highest estimated nutrient concentrations.

The April flow pattern was different to most other months with low and steady flows recorded for a large proportion of the month. The current flow/concentration relationships appeared to perform poorly during April, causing the calculated nitrate concentration and mass load to be higher than that of total nitrogen. Obviously, this cannot be correct but we are confident that, although the values reported are not exact, they are not too far off the real values. This same result was seen in the April 2005 data and appears to be caused when river flows during a winter month are at a steady state for large proportions of the month.

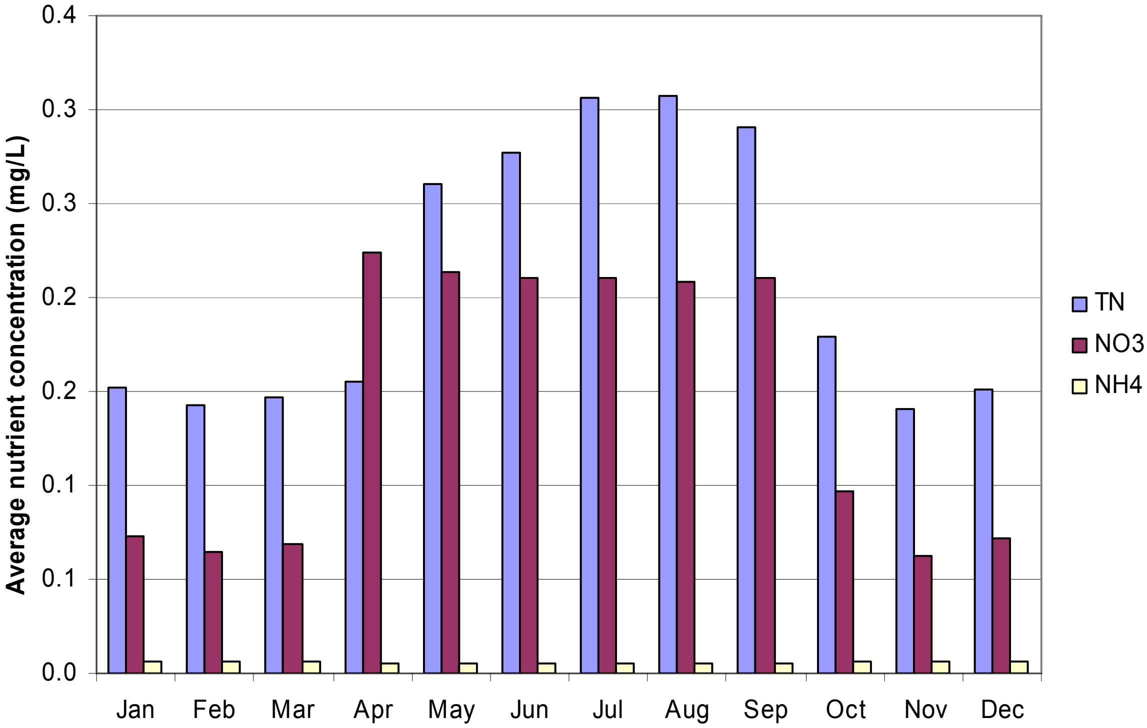

Figure 3. Average daily concentrations of Total Nitrogen (TN), Nitrate (NO_3-N) and Ammonium (NH_4-N) in the Motueka River during 2007.

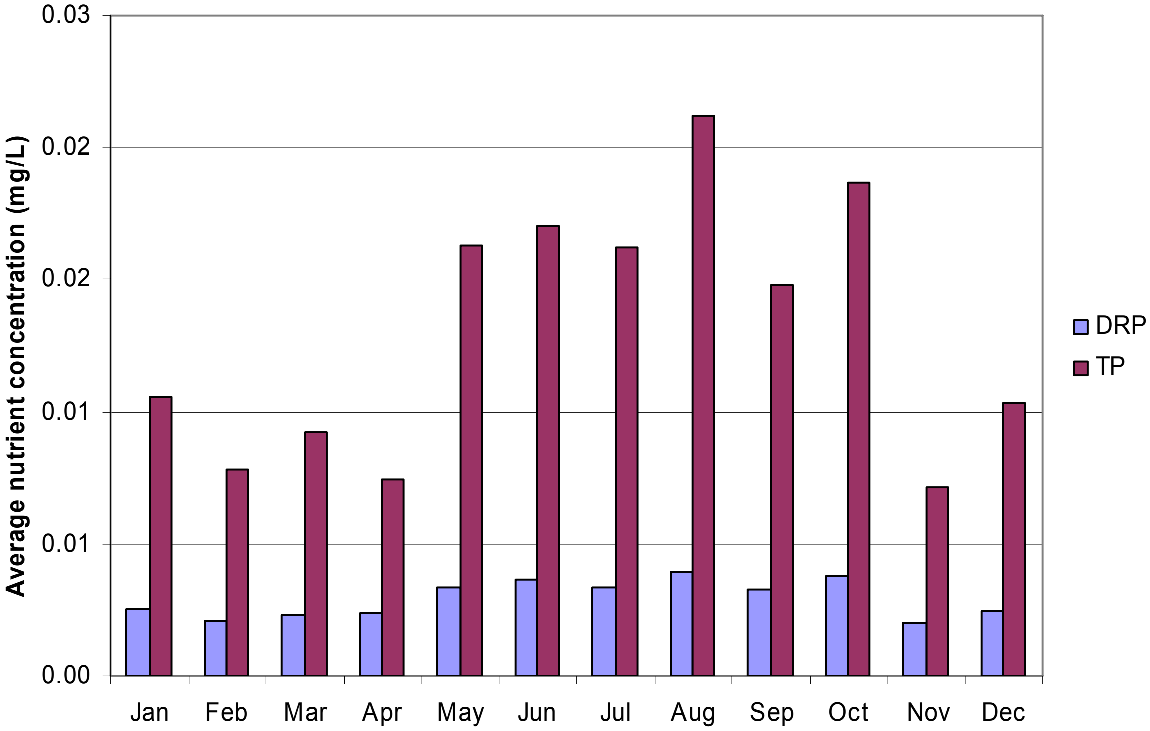

Figure 4. Average daily concentrations of Dissolved Reactive Phosphorus (DRP) and Total Phosphorus (TP) in the Motueka River during 2007.

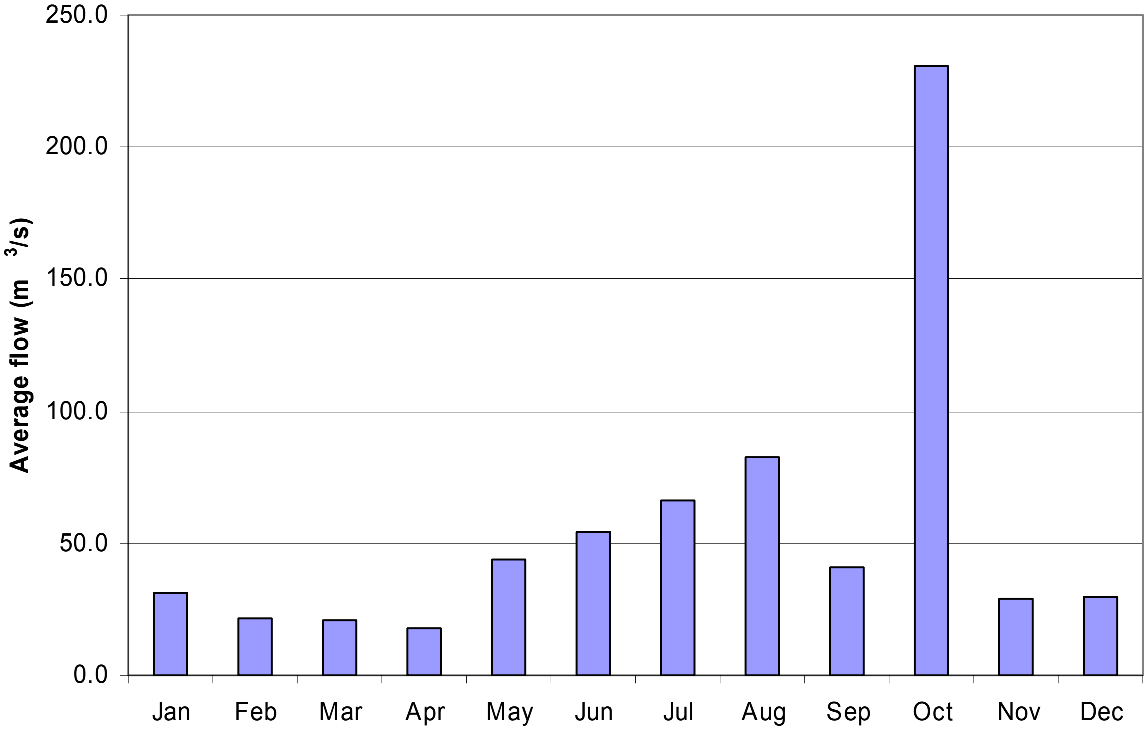

Figure 5. Average flows at Woodman's Bend during 2007.

3.2. Mass nutrient loading to Tasman Bay

Annual loads

The total discharge of each of six nutrient species into Tasman Bay from the Motueka catchment was estimated for the calendar year 2007 (Table 2).

Table 2. Estimated mass discharge of nutrients (tonnes) into Tasman Bay via the Motueka River during 2007.

TN	NO_3-N	NH_4-N	DIN	DRP	TP	DRSi
295	182	10	192	6	28	11310

Monthly loads

Monthly nutrient loadings, controlled by the concentration of the nutrient species and the corresponding river flow, resulted in generally higher loading estimates for the winter months of May-September (Figures 6 and 7). However the highest loading was seen in October, where nutrient loadings were over twice as high as other months, due largely to the much higher river flows seen during this month.

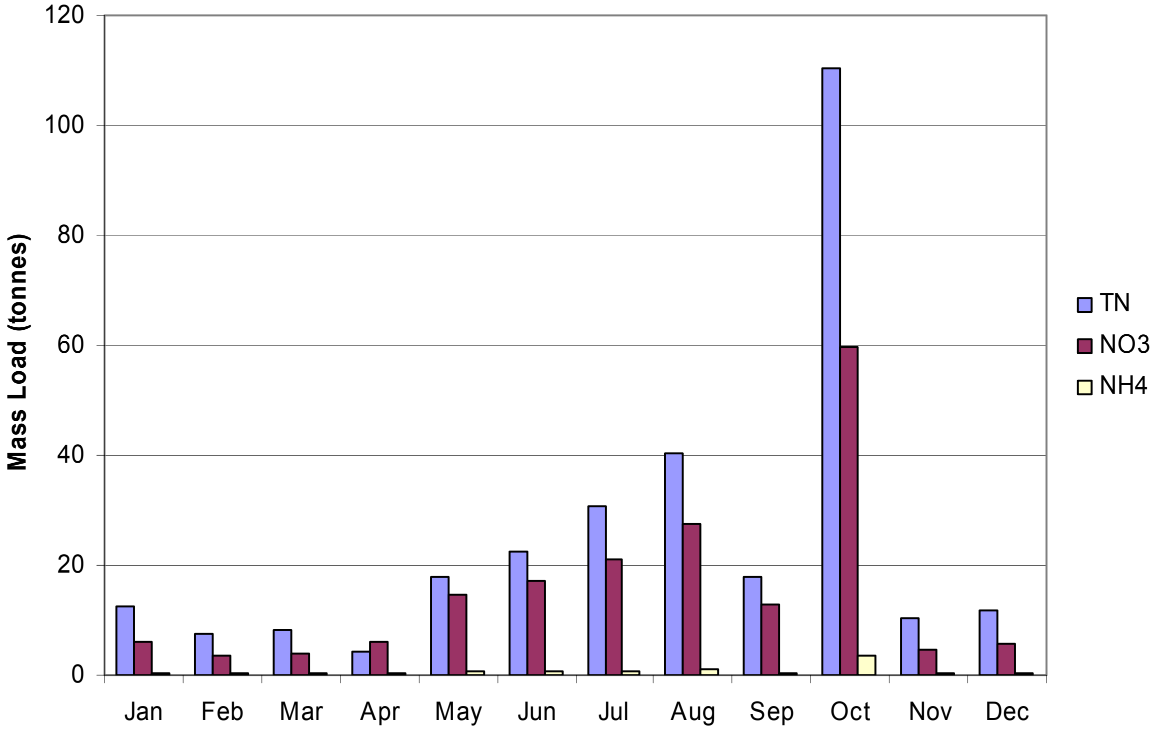

Figure 6. Mass loadings of Total Nitrogen (TN), Nitrate (NO_3-N) and Ammonium (NH_4-N) in the Motueka River during 2007.

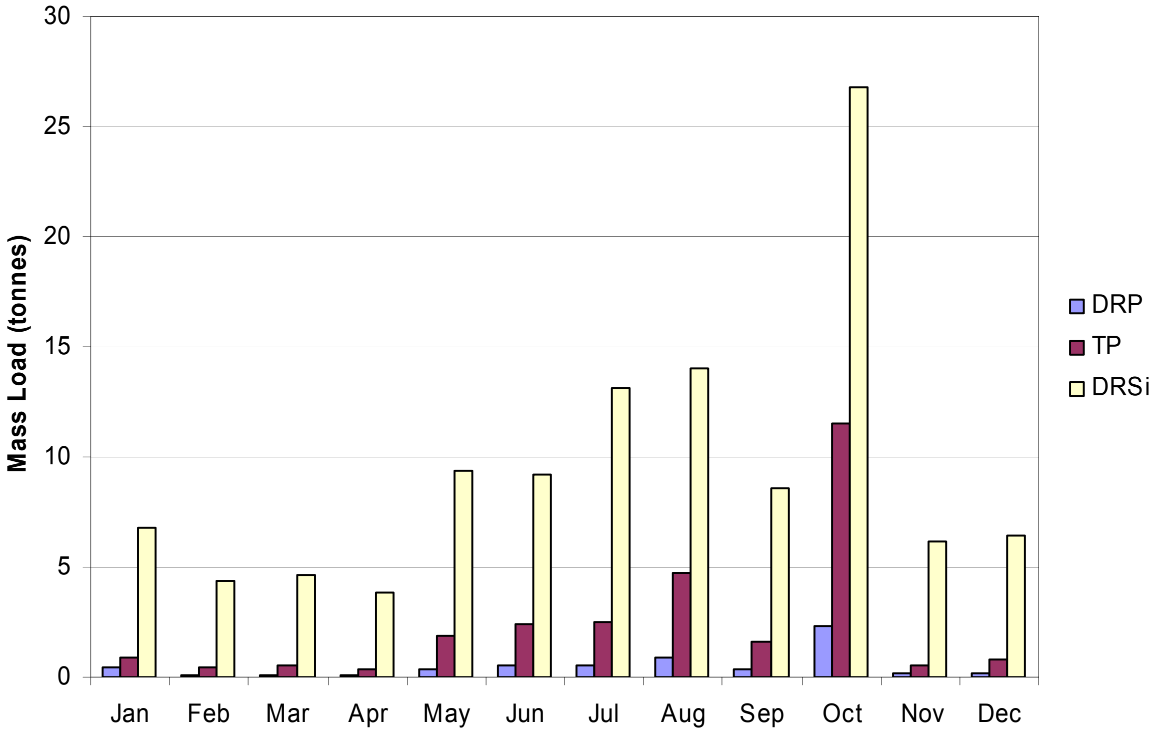

Figure 7. Mass loadings of Dissolved Reactive Phosphorus (DRP), Total Phosphorous (TP) and Dissolved Reactive Silica (DRSi) in the Motueka River during 2007. DRSi values have been divided by 100.

4. DISCUSSION

The results presented here will enable rough comparisons of the various sources of "new" nutrients to Tasman Bay. Although the Motueka River contributes more than 60% of the total freshwater flow into the Bay, it appears that other smaller tributaries (*i.e.* the Waimea, Maitai and Wakapuaka rivers and a number of smaller streams) may contribute a disproportionate amount (*i.e.* ≥50%) of some nutrients (*e.g.* NO_3-N) due to their generally higher concentrations. This assumption, however, is based on a limited amount of water quality data (Gillespie *et al.* 2001).

MacKenzie (2003) reported DRSi concentrations for Tasman Bay surface waters that were generally far in excess of phytoplankton requirements. He described strongly increasing shoreward DRSi gradients off the Motueka River mouth, and an inverse relationship of DRSi with salinity as testimony to the importance of freshwater sources of this nutrient. These findings are consistent with the relatively high Si discharge rates observed in the present study. An optimum molar ratio of DRSi to DIN to DRP for phytoplankton production in temperate coastal waters is considered to be approximately 16:16:1 (Redfield *et al*. 1963). A significant divergence from this ratio could result in an alteration of phytoplankton community structure. For example, where DRSi is relatively less available than DIN in coastal surface waters, diatom-dominated communities could be displaced by others that are less Si-demanding (*e.g.* dinoflagellate-dominated communities). The average DRSi to DIN molar ratio calculated from the Motueka River data was 29 times greater than the optimum 1:1 requirement in 2007. Similar ratios were calculated for 2005 and 2006 (33 and 31 times greater respectively), suggesting that the normally recurring winter/spring and autumnal diatom blooms in Tasman Bay (MacKenzie & Gillespie 1986) are nourished with DRSi from freshwater sources to the extent that concentrations are unlikely to be limiting in plume-affected regions.

Molar DIN to DRP ratios of inflowing Motueka river waters are generally high (mean = 74 in 2005 and 71 in 2006 and 2007) suggesting that algal growth in the river may have been (at times) phosphorus limited, although N:P ratios generally provide a poor indicator of which nutrient is limiting in rivers and streams (Francoeur *et al*. 1999). The coastal waters of Tasman Bay, however, are known to be limited to a greater extent by nitrogen with molar N to P ratios typically less than 16 to 1 (MacKenzie *et al*. 2003). In view of this, we look more closely at known sources and sinks for nitrogen in Tasman Bay and their significance to coastal productivity.

Using TN as an example, the total freshwater + wastewater input to Tasman Bay during 2007 would be approximately 870 tonnes. This total includes 295 tonnes from the Motueka River (this study), 273 tonnes from other tributaries of Tasman Bay (very rough but conservative estimate based on proportional flows and limited available water quality data) and 304 tonnes from the four main point source wastewater discharges (Gillespie *et al*. 2001). By extrapolating measured Tasman Bay benthic denitrification rates (two sites only, Christensen *et al*. 2003) to the <30 m depth contour of the Bay, we estimate that about 1,800 tonnes of TN could be removed per year. Thus it appears that the amount of TN discharged into the Bay during 2007 would have been easily assimilated and would have contributed to coastal production in a beneficial way with little potential for dysfunctional ecosystem enrichment effects.

The estimated total mass transport loads of the various nutrients into Tasman Bay from the Motueka River were considerably higher for 2007 than for 2005 but very similar to those for 2006 (Clark *et al*, 2007). However, the unusual discharge pattern during 2007, with a major peak during October, could have affected the timing and magnitude of the "normal" seasonal phytoplankton peaks (*i.e* winter/spring and autumn bloom periods). This question will be addressed separately through long-term *in situ* data collection and coastal ecosystem modelling. Such variations in phytoplankton biomass, should they occur, could theoretically also result in follow-on variation in the success of commercial shellfish spat collection and shellfish growth rates within western Tasman Bay.

5. ACKNOWLEDGEMENTS

Flow/concentration relationships were developed by Richard Nottage. See Appendix 1 in Gillespie *et al*. (2006) for more details of these relationships and how they were calculated. Year to year comparisons were facilitated through modifications recommended by Ben Knight, Cawthron.

Unpublished Motueka River water quality data was provided by Dr Roger Young (Cawthron Institute), Graham Bryers (NIWA, Hamilton) and Trevor James (Tasman District Council, Richmond). River flow data was provided by Martin Doyle (Tasman District Council, Richmond).

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