Nutrient Loading from the Motueka River into Tasman Bay, 2005 and 2006

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Nutrient Loading from the Motueka River into Tasman Bay, 2005 and 2006

Kim Clark
Paul Gillespie
Reid Forrest

Prepared for
Stakeholders of the
Motueka Integrated Catchment Management Programme

Cawthron Institute
98 Halifax Street East, Private Bag 2
Nelson, New Zealand
Ph. +64 3 548 2319
Fax. + 64 3 546 9464
www.cawthron.org.nz

Reviewed by: ______________ Approved for release by: ______________
Roger Young Rowan Strickland

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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 top 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 calendar years 2005 and 2006. 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). Although the 2005 data was presented in that report, the re-calculated nutrient discharge values in the present report have been prepared using a slightly different, more repeatable method that was also used to calculate the 2006 results. Therefore it is recommended that these new 2005 results are used when comparing nutrient discharge rates between years.

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, for both years, high concentrations of a number of nutrient species were also estimated to have occurred during April and September.

The estimated mass transport of nutrients into Tasman Bay via the Motueka River during the calendar years 2005 and 2006 was:

	Average flow (m^3/s)	TN (t)	NO_3(t)	NH_4 (t)	DIN (t)	DRP (t)	TP (t)	DRSi (t)
2005	38	190	125	6	133	4	17	9005
2006	55	293	182	9	192	6	29	12258

The calculated amounts of all nutrients entering the Bay were considerably greater during 2006 than 2005. This was largely due to higher river flows during 2006. Relatively high discharges for most nutrient species were indicated for January, June, July and August 2005 as opposed to April and November in 2006.

The flow/concentration relationships described here and the resulting 2005 and 2006 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 year to year variations in the annual nutrient discharge and monthly delivery patterns, however, would be expected to affect phytoplankton production rates and seasonal cycles with possible follow-on implications for shellfish resources.

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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 top 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 (Gillespie *et al*. 2006). The present report uses the same flow/concentration relationships to estimate the discharge rates of nutrients during 2006 and reports re-calculated rates for 2005. The nutrients evaluated were total phosphorus (TP), dissolved reactive phosphorous (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 and for the 2005 and 2006 calendar years. 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, 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.

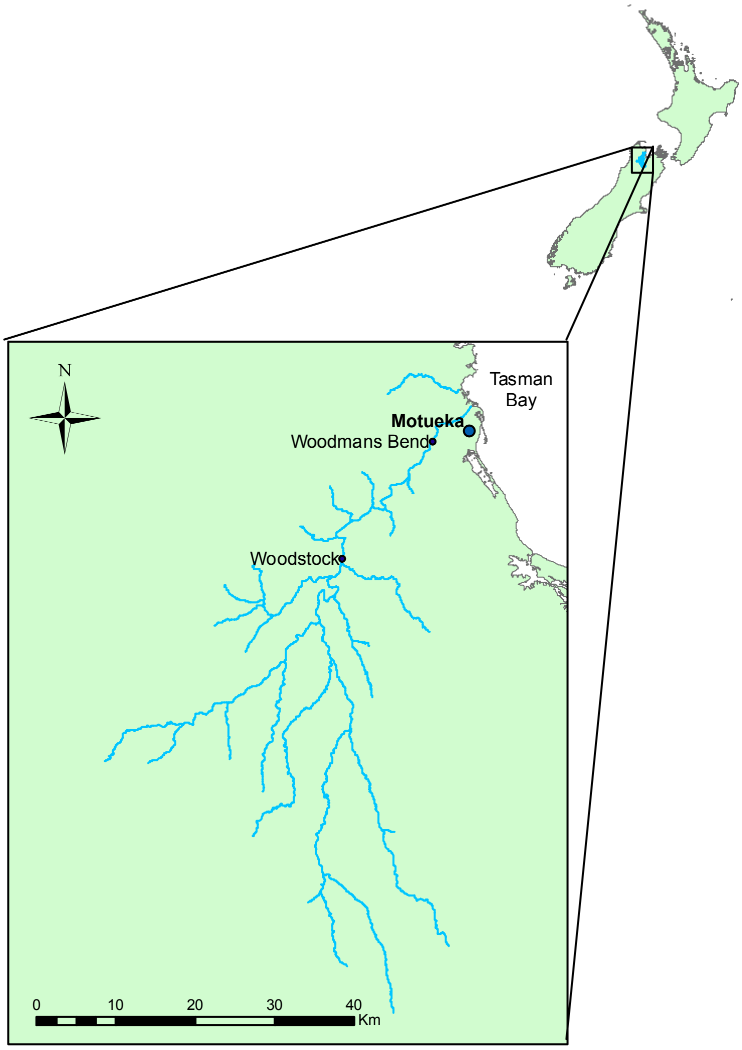

Figure 1. Location map of the Motueka catchment and data collection points.

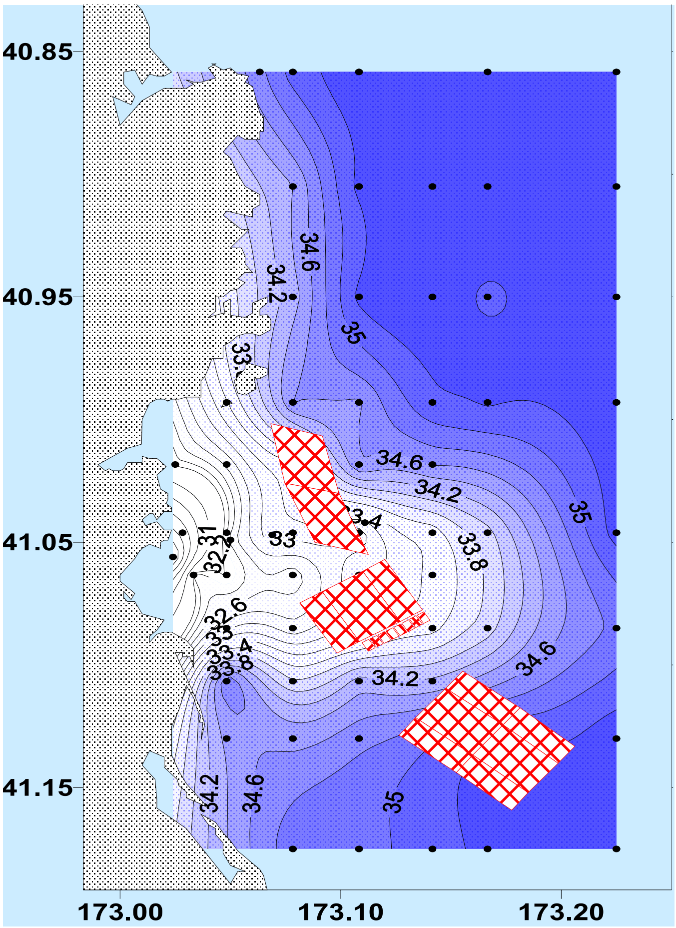

Figure 2. Spatial extent of the Motueka River outwelling plume (surface salinity field) after a moderate rainfall event with flows up to 200 m^3s^{-1} (from Tuckey *et al.* 2006).

2. METHODS

This report follows on from a previous study looking at nutrient loadings in the Motueka River during 2005 (Gillespie *et al*. 2006). In the course of the present study a new, more objective method was adopted 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 previously. In order to ensure comparability between the two years, the nutrient concentrations and loadings for 2005 were re-calculated and the updated results are reported here. Although the monthly patterns have remained fairly similar, the mass loadings of some nutrients have changed slightly. As it is intended that the new method will continue to be used in subsequent years, the updated values for 2005 reported here 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^{3}s^{-1} and average concentrations >80 m^{3}s^{-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) = $(conc_{steady} \times t_{steady}) + (conc_{rise} \times t_{rise}) + (conc_{recede} \times t_{recede})$

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

$$\text{Mass Load (kg/day)} = V_{flow} \times conc_{avg}$$

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. 2005

3.1.1. 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 species. For example, nitrate concentrations were highest in April – September, while total and dissolved phosphorus concentrations were highest in June – August (Figures 3 and 4). Highest concentrations were generally consistent with periods of high flows (Figure 5). Of the summer months, January and March produced the highest estimated nutrient concentrations and river flows.

The April flow pattern was different to most other months with steady flows recorded for a large proportion of the month. The current flow/concentration relationships appeared to perform poorly during April and May, 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. Hopefully, this flaw in the flow/concentration relationship during unusual flow patterns can be rectified with additional data in future.

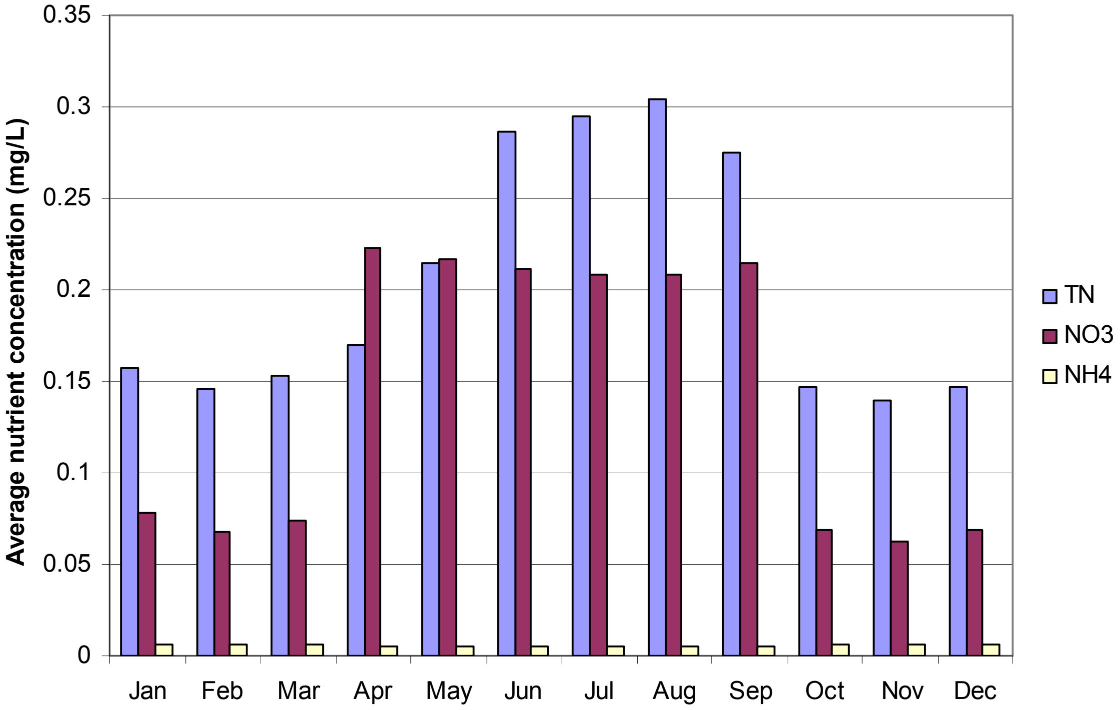

Figure 3. Average daily concentrations of Total Nitrogen (TN), Nitrate (NO_3-N) and Ammonium (NH_4-N) in the Motueka River during 2005.

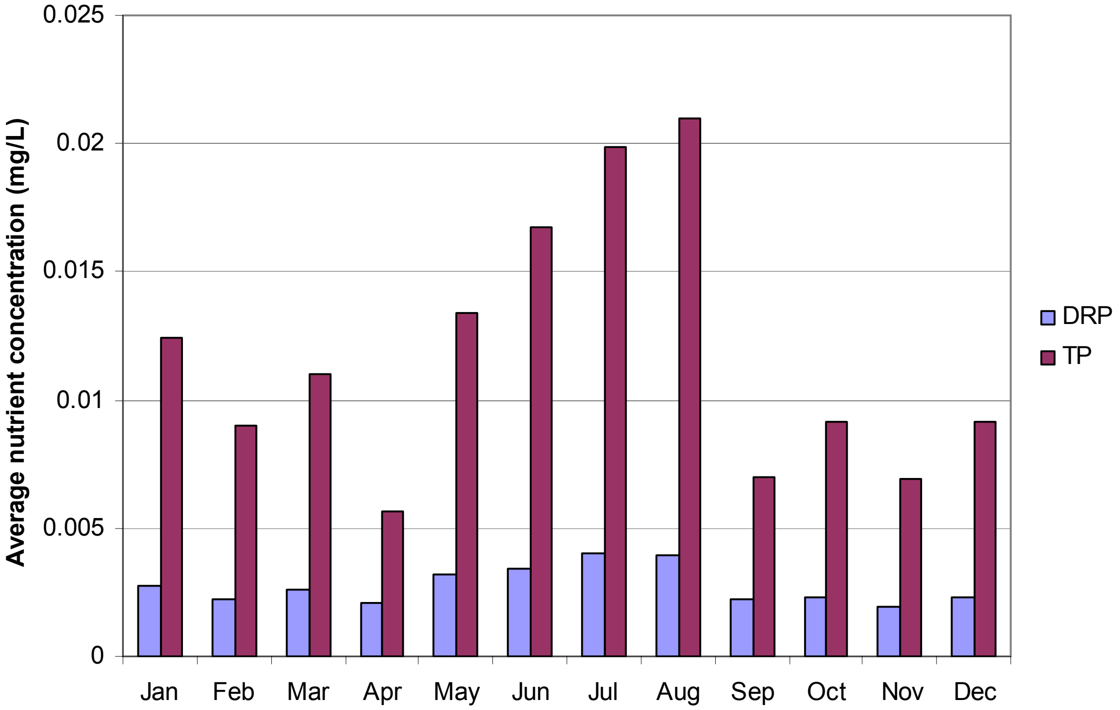

Figure 4. Average daily concentrations of Dissolved Reactive Phosphorus (DRP) and Total Phosphorus (TP) in the Motueka River during 2005.

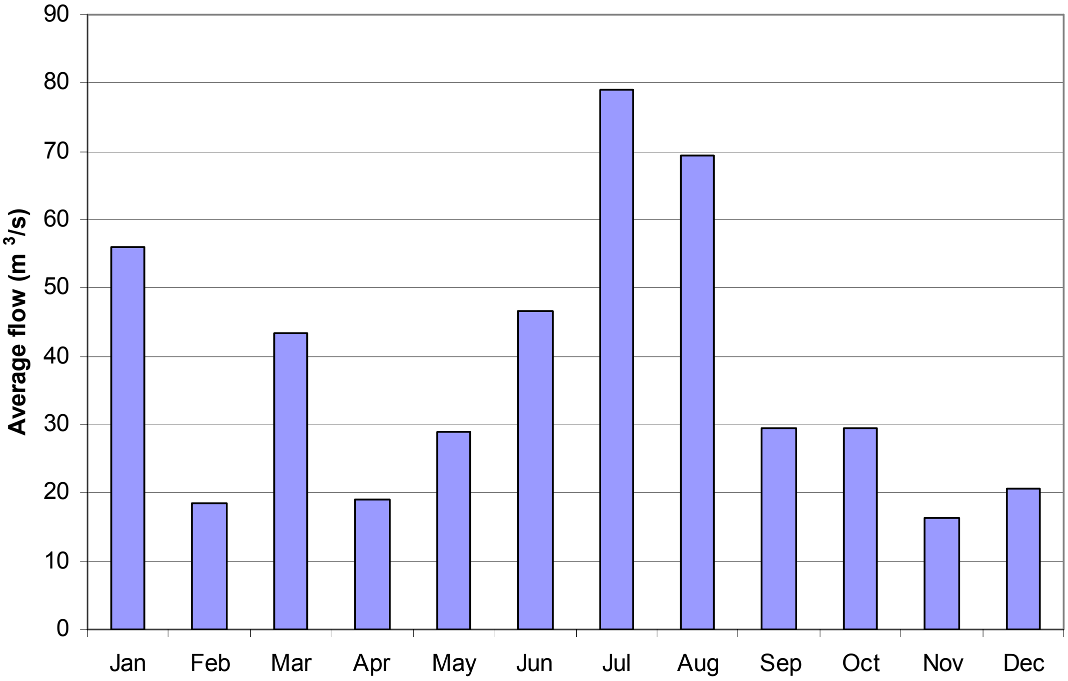

Figure 5. Average flows at Woodman's Bend during 2005.

3.1.2. 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 2005 (Table 2).

Table 2. Estimated mass discharge of nutrients (tonnes) into Tasman Bay via the Motueka River during 2005.

TN	NO_3-N	NH_4-N	DIN	DRP	TP	DRSi
190	125	6	133	4	17	9005

Average 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, June – August 2005 (Figures 6 and 7). Higher loading rates for TN, TP and DRSi were also indicated for January and March corresponding to particularly high summer flows during those months.

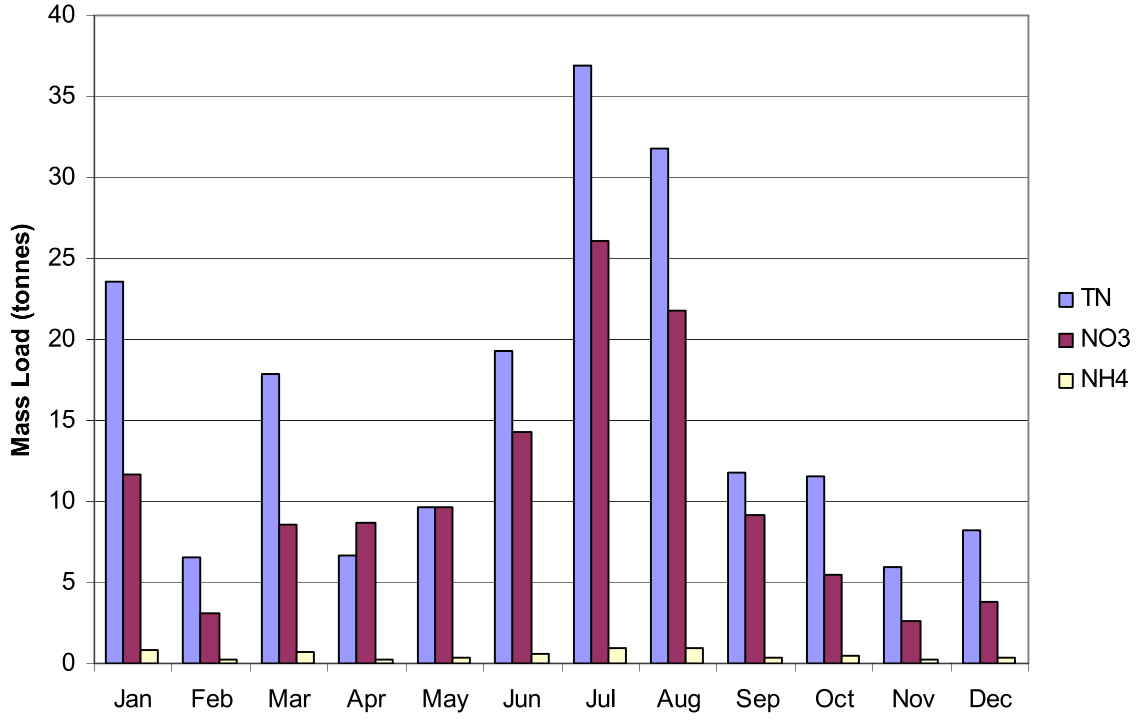

Figure 6. Mass Loadings of Total Nitrogen (TN), Nitrate (NO_3-N) and Ammonium (NH_4-N) in the Motueka River during 2005.

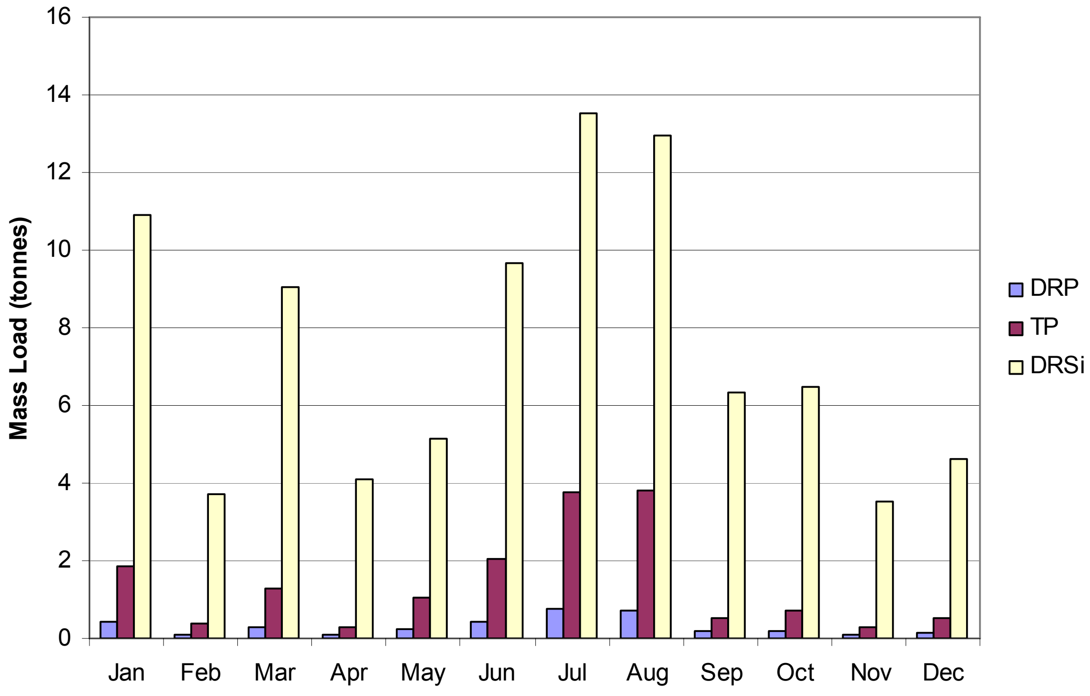

Figure 7. Mass Loadings of Dissolved Reactive Phosphorus (DRP), Total Phosphorous (TP) and Dissolved Reactive Silica (DRSi) in the Motueka River during 2005. DRSi values have been divided by 100.

3.2. 2006

3.2.1. *Average nutrient concentrations*

Higher river water concentrations of TN and NO_3-N were indicated for the period April - September (Figure 8) with generally lower concentrations for the summer months. This relationship was less apparent (Figure 9) for DRP (little seasonal variation) and TP (relatively higher summer concentrations). Once again a general relationship with river flow (Figure 10) is obvious.

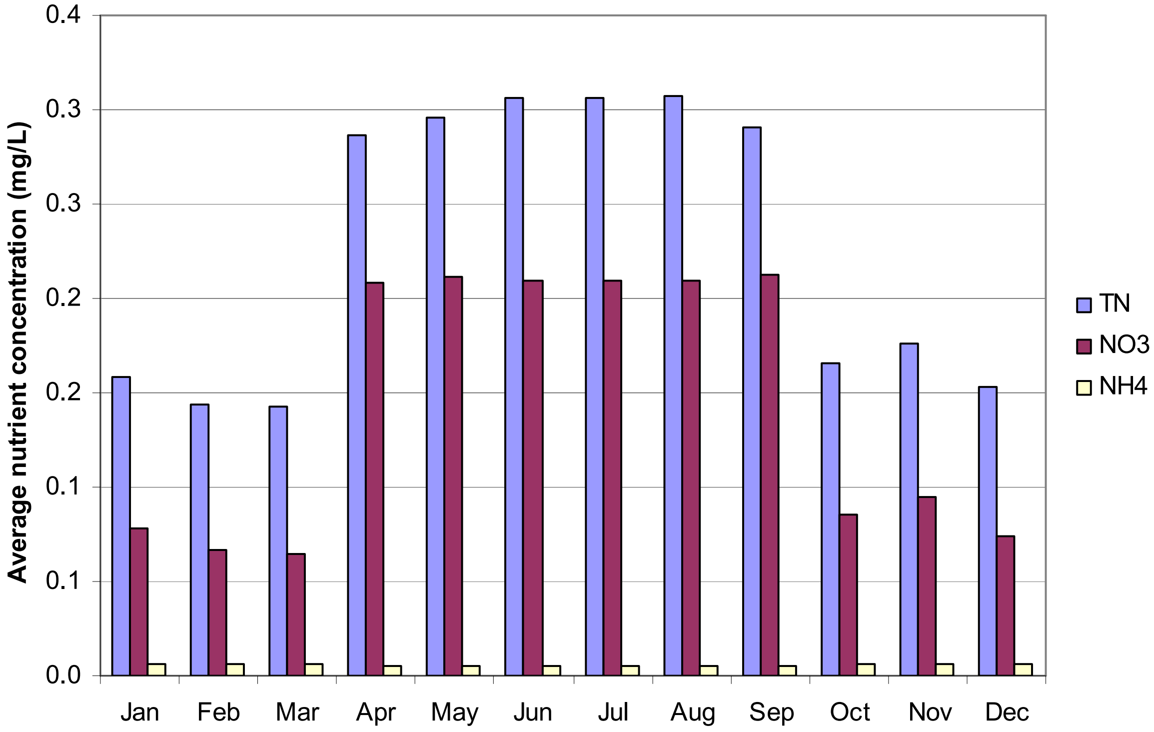

Figure 8. Average daily concentrations of Total Nitrogen (TN), Nitrate (NO_3-N) and Ammonium (NH_4-N) in the Motueka River during 2006.

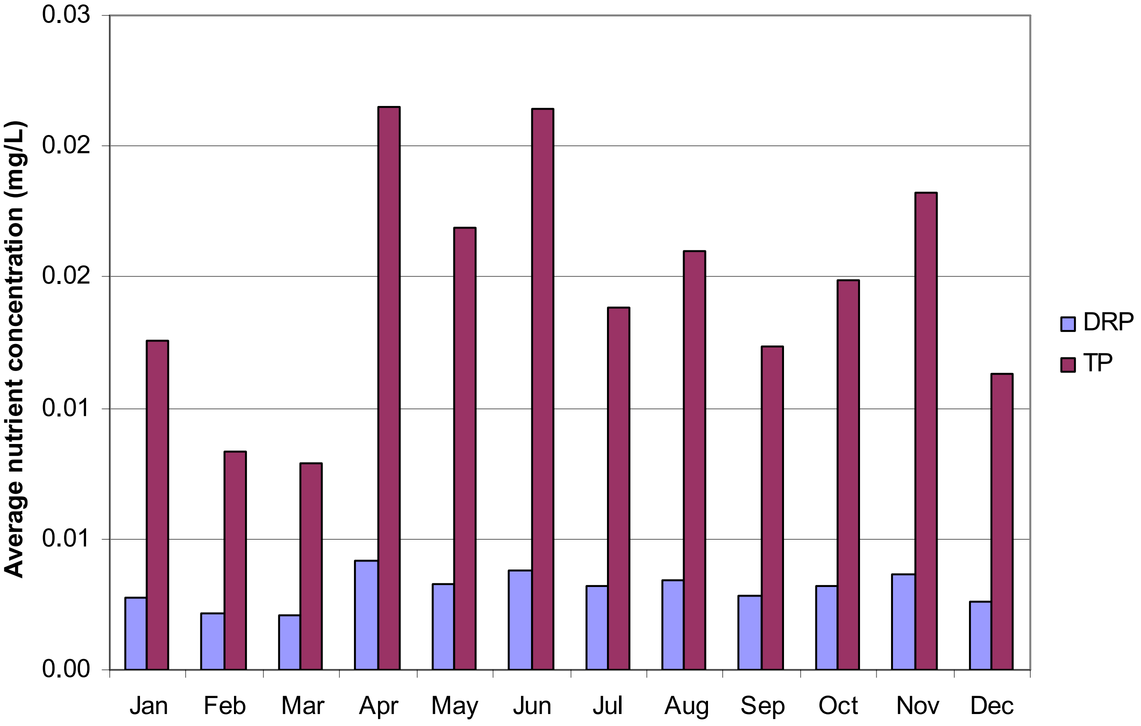

Figure 9. Average daily concentrations of Dissolved Reactive Phosphorus (DRP) and Total Phosphorus (TP) in the Motueka River during 2006.

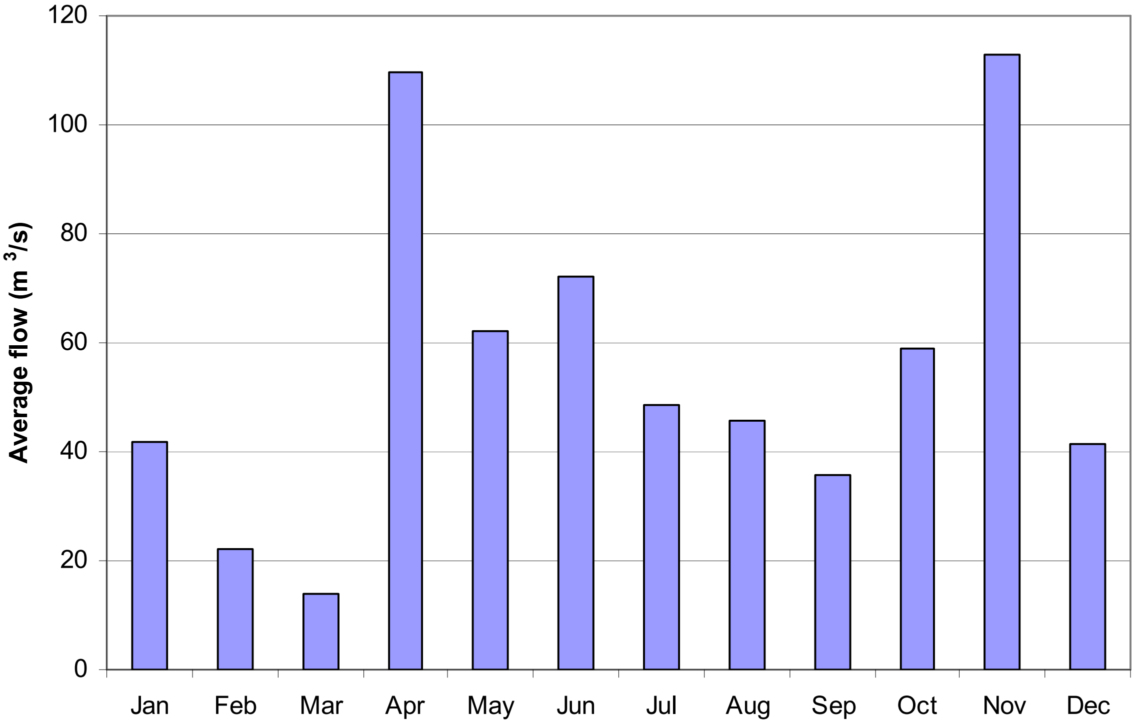

Figure 10. Average flows at Woodman's Bend during 2006.

3.2.2. Mass nutrient loading to Tasman Bay

Annual loads

The total discharges of each of six nutrient species into Tasman Bay from the Motueka catchment were estimated for the calendar year 2006 (Table 3).

Table 3. Estimated mass discharge of nutrients (tonnes) into Tasman Bay via the Motueka River during 2006.

TN	NO_3-N	NH_4-N	DIN	DRP	TP	DRSi
293	182	9	192	6	29	12258

Average monthly loads

The highest average nutrient loadings over the 2006 calendar year were estimated to occur during April and November, however slightly elevated loadings were also indicated during May and June (Figures 11 and 12), corresponding to higher flows during this period (Figure 10).

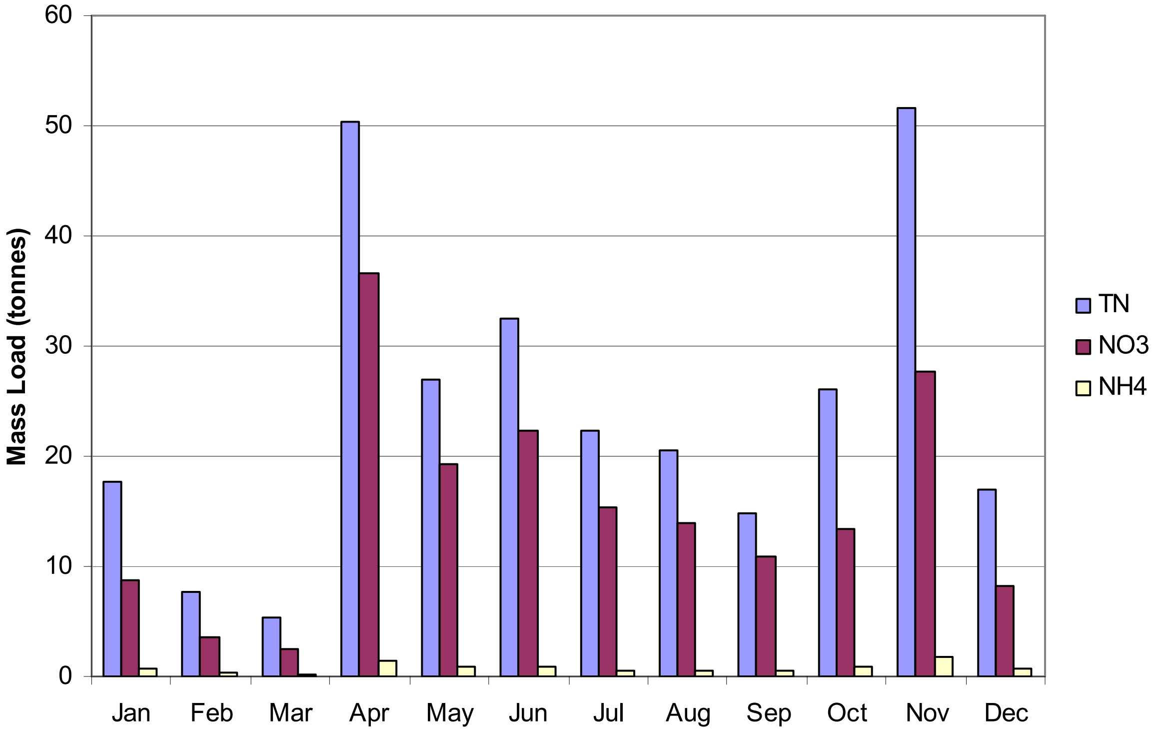

Figure 11. Mass Loadings of Total Nitrogen (TN), Nitrate (NO_3-N) and Ammonium (NH_4-N) in the Motueka River during 2006.

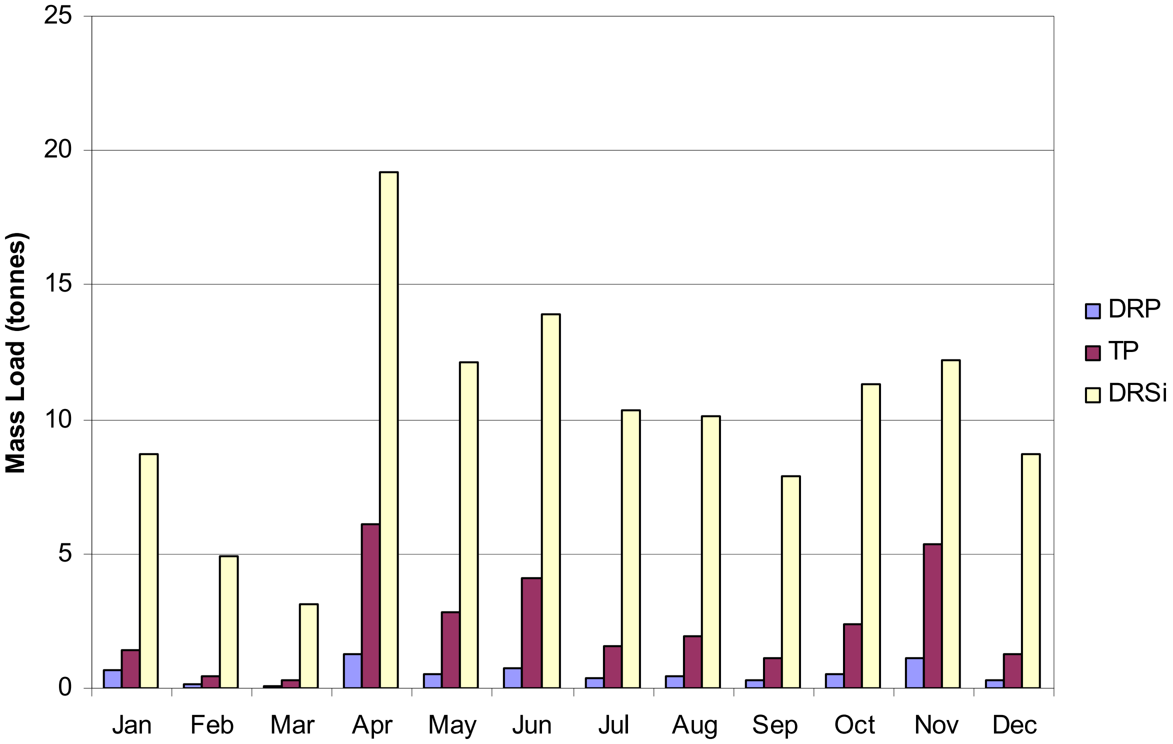

Figure 12. Mass Loadings of Dissolved Reactive Phosphorus (DRP), Total Phosphorus (TP) and Dissolved Reactive Silica (DRSi) in the Motueka River during 2006. DRSi values have been divided by 100.

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.* NO3-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 33 times greater than the optimum 1:1 requirement in 2005 and 31 times greater in 2006, 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 were high (mean = 74 in 2005 and 71 in 2006) 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 2006 would be approximately 870 tonnes. This total includes 293 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 both 2005 and 2006 would have been easily assimilated and would have contributed to coastal production in a beneficial way with little potential for dysfunctional ecosystem enrichment effects.

Considerable variations were observed in the annual nutrient discharge and monthly loading pattern between 2005 and 2006. The considerably higher nutrient inflows during 2006 would likely have resulted in an increased phytoplankton production in the Bay. Perhaps more importantly, however, the contrasting discharge pattern during 2006, with a major peak during autumn, 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 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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