The effect of residence time and hypoxia on nitrogen loading in the Yarra River Estuary, Australia

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N-limited Port Phillip Bay


*CSIRO (1996) Port Phillip Bay Study*
N-limited Port Phillip Bay

WTP ~ 50% TN

Yarra River ~ 25% TN

* CSIRO (1996) Port Phillip Bay Study

N-limited Port Phillip Bay

The Yarra River estuary provides the final stage of N-processing.

Yarra River ~ 25% TN


* CSIRO (1996) Port Phillip Bay Study
- Low freshwater inflow
- Residence time of bottom water can be weeks to months
- Stratification and isolation of saline bottom waters
- Depletion $O_2$ – hypoxic or anoxic conditions

freshwater
(NH$_4^+$, NO$_3^-$, O$_2$)

hypoxic sediment

% $O_2$
0 100
- High freshwater inflow
- Induces mixing, re-oxygenates bottom water, residence time hours to days
Residence time and nitrogen loads


\[ y = 20.8 \log(x) + 22.4 \]
\[ r^2 = 0.75 \]

\[ y = -27.0 \log(x) + 64.8 \]
\[ r^2 = 0.88 \]
Is this true for the Yarra River estuary?
Calculating DIN loads

- Flow and nutrients gauged at Chandler Hwy, Merri Creek, Gardiners Ck
Calculating DIN loads

- Flow and nutrients gauged at Chandler Hwy, Merri Creek, Gardiners Ck

- Measured rates of denitrification, DNRA, fluxes of $\text{NO}_3^-$ and $\text{NH}_4^+$
DIN pathways

A

\[ \text{NO}_x \rightarrow \text{D}_{w} \rightarrow \text{Removed } N_2 \]
\[ \text{NO}_x \rightarrow \text{DNRA}_{w} \rightarrow \text{Recycled } \text{NH}_4^+ \]
\[ \text{NO}_x \rightarrow \text{Mineralisation} \]

B

\[ \text{NH}_4^+ \rightarrow \text{NO}_x \rightarrow \text{Mineralisation} \]
\[ \text{NO}_x \rightarrow \text{D}_{n} \rightarrow \text{Removed } N_2 \]
\[ \text{NO}_x \rightarrow \text{DNRA}_{n} \rightarrow \text{Recycled } \text{NH}_4^+ \]
\[ \text{NH}_4^+ \rightarrow \text{Nitrification} \]
DIN loads

NO$_3^-$ (kg N/day)

INPUT
Load after processing
Oxygen

NH$_4^+$ (kg N/day)

INPUT
Load after processing
Oxygen


O$_2$ (µmol L$^{-1}$)


O$_2$ (µmol L$^{-1}$)

INPUT
Load after processing
Oxygen

NH$_4^+$ (kg N/day)


O$_2$ (µmol L$^{-1}$)

INPUT
Load after processing
Oxygen

NH$_4^+$ (kg N/day)


O$_2$ (µmol L$^{-1}$)

INPUT
Load after processing
Oxygen
DIN loads

No net NO$_3^-$ removal

NH$_4^+$ Addition

INPUT Load after processing Oxygen

NH$_4^+$ (kg N/day) NO$_3^-$ (µmol L$^{-1}$)

O$_2$ (µmol L$^{-1}$)

Residence time and nitrogen loads

Other estuarine systems

Residence time
N-removal

Yarra River estuary

Residence time
N-removal
Why?
Why?

1. Freshwater inflow
2. Stratification & Hypoxia
3. Denitrification
1. Freshwater inflow N-loads

- Freshwater inflow N-loads
- Flow
- $\text{NO}_3^-$
- $\text{NH}_4^+$
1. Freshwater inflow N-loads

LOW summer rainfall = high residence time (weeks) of bottom water leads to HYPOXIA

HIGH summer rainfall = low residence time of bottom water (hours to days)
1. Freshwater inflow and N-loads

- The highest N-loads are input during high flow. The residence time under these conditions is hours to days.

NOT enough time for significant N-removal to occur.
2. Stratification and Hypoxia

- Under low flow conditions the residence time is **weeks to months** leading to **low oxygen** conditions in the bottom waters.
2. Stratification and Hypoxia

- Under low flow conditions the residence time is **weeks to months** leading to **low oxygen** conditions in the bottom waters.
Anoxic conditions disconnect between \( \text{NH}_4^+ \) produced via mineralisation and nitrification-denitrification coupling

**Efflux of \( \text{NH}_4^+ \) from the sediment**
3. Denitrification

**Denitrification**

\[
\text{NO}_3^- \rightarrow \text{N}_2
\]

Denitrification < efflux of \(\text{NH}_4^+\) from mineralisation counteracting the DIN removal

**DNRA**

\[
\text{NO}_3^- \rightarrow \text{NH}_4^+
\]

Denitrification ~ DNRA

\(\text{N}_2\) removed ~ \(\text{NH}_4^+\) recycled

Denitrification removed <2% water column \(\text{NO}_3^-\)

CONCLUSION

Yarra River estuary

Residence time
N-removal

Residence time
N-removal

MANAGEMENT

Catchment N-loads
Reduce stratification/hypoxia

IMPORTANT!! Consider estuarine type in the management of N-loads