3. BUDGETS FOR ESTUARIES IN JAPAN

3.1 Dokai Bay

Tetsuo Yanagi

<u>Study area description</u>

Dokai Bay is a hyper-eutrophicated semi-enclosed bay, located in the northern part of Kyushu, the main western island of Japan (Figure 3.1). Its volume is 88×10^6 m^3, surface area 11 km^2, average depth 8 m, width 1 km and bay length 11 km.

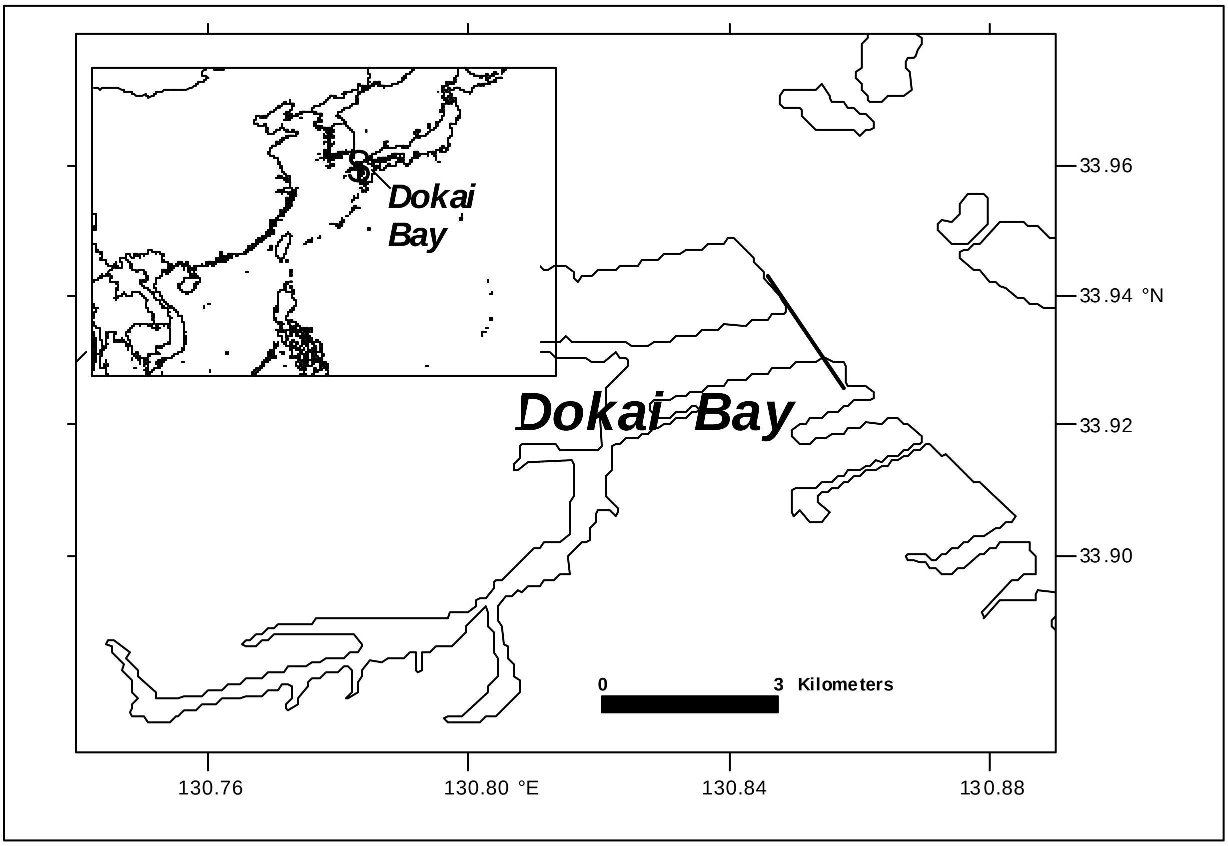

Figure 3.1. Map and location of Dokai Bay, Japan. The limit of the budgeted area. is marked.

Intensive field observations of water temperature, salinity, nitrogen and phosphorus were conducted at 1-meter depth intervals at seven stations on 20 August 1998. Results are shown in Figure 3.2. Water mass with low salinity, small density and high concentrations of TP and TN flows into the head of the bay. Such distributions of salinity and nutrients are considered to be quasi-steady state because their temporal variations are much smaller than their spatial variations (Yanagi and Yamada 2000).

<u>Water and salt balance</u>

Figure 3.3 shows the water and salt budgets. Here 30.7 psu is the average salinity from Station 2 to Station 7 and 31.3 psu at Station 1. The residual volume transport from Dokai Bay V_R is 81×10^3 m^3 d^{-1} and the mixing volume across the open boundary V_X is estimated to be $4,185\times10^3$ m^3 d^{-1} which is about 50 times that of V_R.

<u>Budgets of nonconservative materials</u>

DIP and DOP budgets

DIP and DOP budgets are shown in Figure 3.4(a) and (b). Concentrations of DIP and DOP in the bay are 2.1 μM and 0.7 μM, respectively. DIP of 115 mol d^{-1} is transformed to organic form and DOP of 7 mol d^{-1} is transformed to DIP or POP.

DIN and DON budgets

DIN and DON budgets are shown in Figure 3.5(a) and (b). Concentrations of DIN and DON in the bay are 95 μM and 37 μM, respectively. DIN of 9×10^{3} mol d^{-1} is transformed to organic form and DON of 2×10^{3} mol d^{-1} is generated from DIN or PON.

POP and PON budgets

POP and PON budgets are shown in Figure 3.6(a) and (b). POP of 2×10^{3} mol d^{-1} and PON of 13×10^{3} mol d^{-1} are decomposed in Dokai Bay.

Stoichiometric calculations of aspects of net system metabolism

When we assume that the main primary producer in Dokai Bay is phytoplankton and the Redfield ratio, C:P = 106:1, is applied, the net primary production in Dokai Bay is estimated to be (*p-r*) = 12×10^{3} mol d^{-1} (1 mmol C m^{-2} d^{-1}).

Nitrogen fixation minus denitrification (*nfix-denit*) flux is estimated by the following formula:

$$(nfix\text{-}denit) = (DDIN)-(DDIP)(N:P)_{part} \qquad (1)$$

$$(nfix\text{-}denit) = (DDIN+DDON)-(DDIP+DDOP)(N:P)_{part} \qquad (2)$$

Here $(N:P)_{part}$ denotes the mol ratio of PON and POP in Dokai Bay which is shown in Figure 3.6. Denitrification calculated using Equation (1) is 7×10^{3} mol d^{-1} (0.6 mmol m^{-2} d^{-1}) while 5×10^{3} mol d^{-1} (0.5 mmol m^{-2} d^{-1}) using Equation (2).

Comparison of the results of nitrogen budget in narrow and deep Dokai Bay and wide and shallow Hakata Bay (Yanagi 1999) is shown in Table 3.1.

Table 3.1. Comparison between Hakata Bay and Dokai Bay.

System	**Volume** (10^{8} m^{3})	**Depth** (m)	**TN load from land** (10^{5} mol d^{-1})	**TN load by release** (10^{5} mol d^{-1})	**TN load** (mmol m^{-3} d^{-1})	**TN** (μM)
Hakata Bay	4	7	9	4	3	35 (14)
Dokai Bay	1	8	5	1	1	143 (33)

System	**TN** (days)	**PP** (gC m^{-2} day^{-1})	**PON** (μM)	**DIN:DON:PON**
Hakata Bay	9.5	0.33	8	2.1:1.1:1.0
Dokai Bay	16.7	0.01	11	8.6:3.4:1.0

Ratio of TN load per unit volume in Dokai Bay to that in Hakata Bay is 2.1 but that of TN concentration is 4.1. This means that Dokai Bay becomes eutrophicated easily compared with Hakata Bay. Such difference may result from the longer residence time of TN in Dokai Bay, where the trapping effect of nitrogen is dominant in a narrow and deep semi-enclosed bay with dominant estuarine circulation as schematically shown in Figure 3.7.

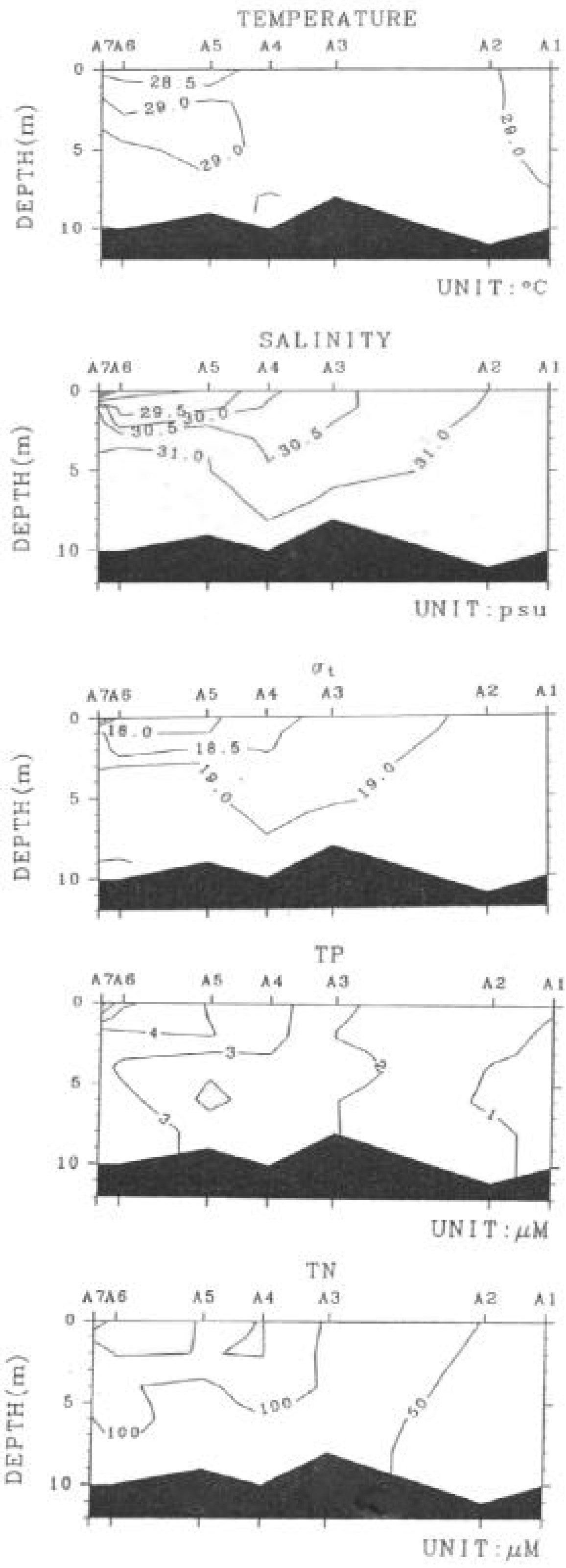

Figure 3.2. Vertical distributions of water temperature, salinity, density, total phosphorus and total nitrogen on 20 August 1998.

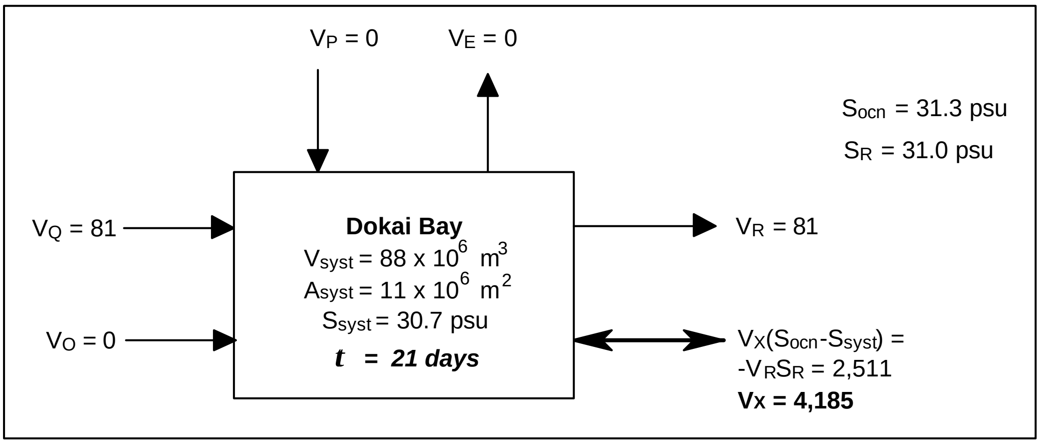

Figure 3.3. Water and salt budgets for Dokai Bay. Water flux in 10^3 m^3 d^{-1} and salt flux in 10^3 psu-m^3 d^{-1}.

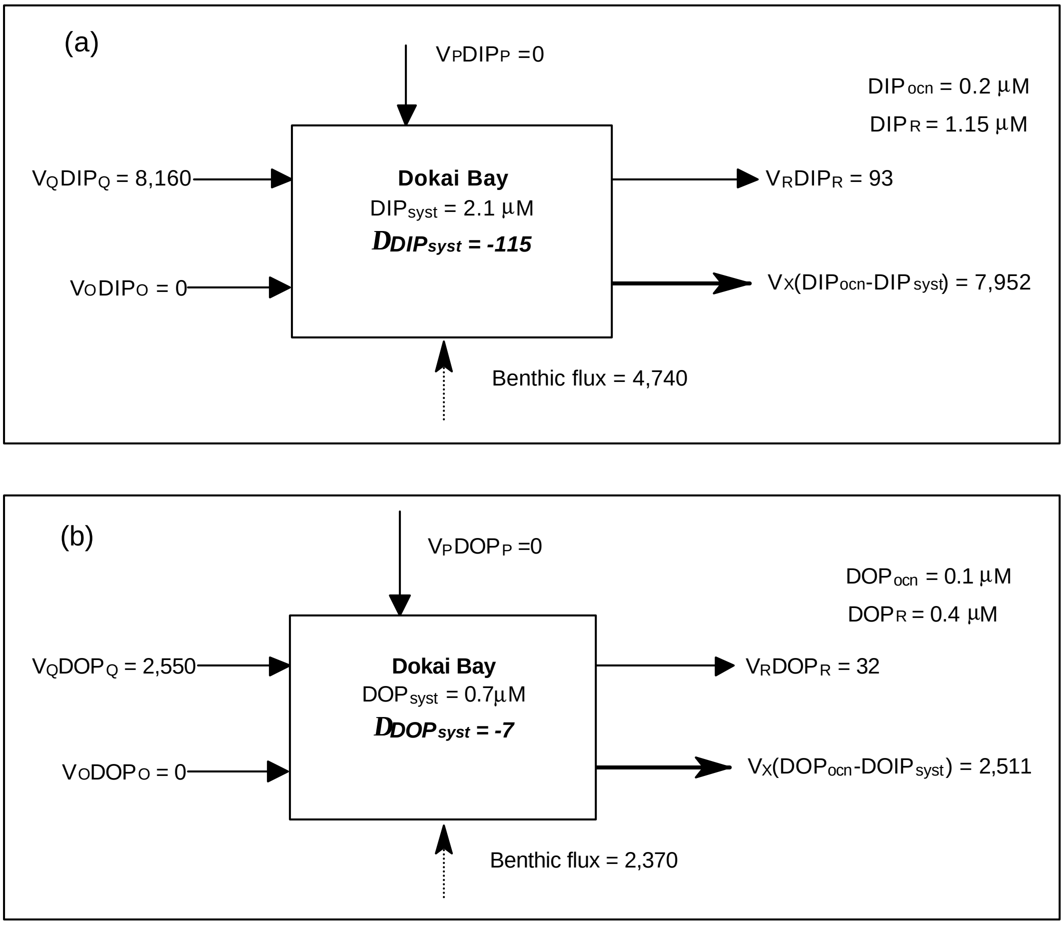

Figure 3.4. DIP (a) and DOP (b) budgets for Dokai Bay. Flux in 10^3 mol d^{-1}.

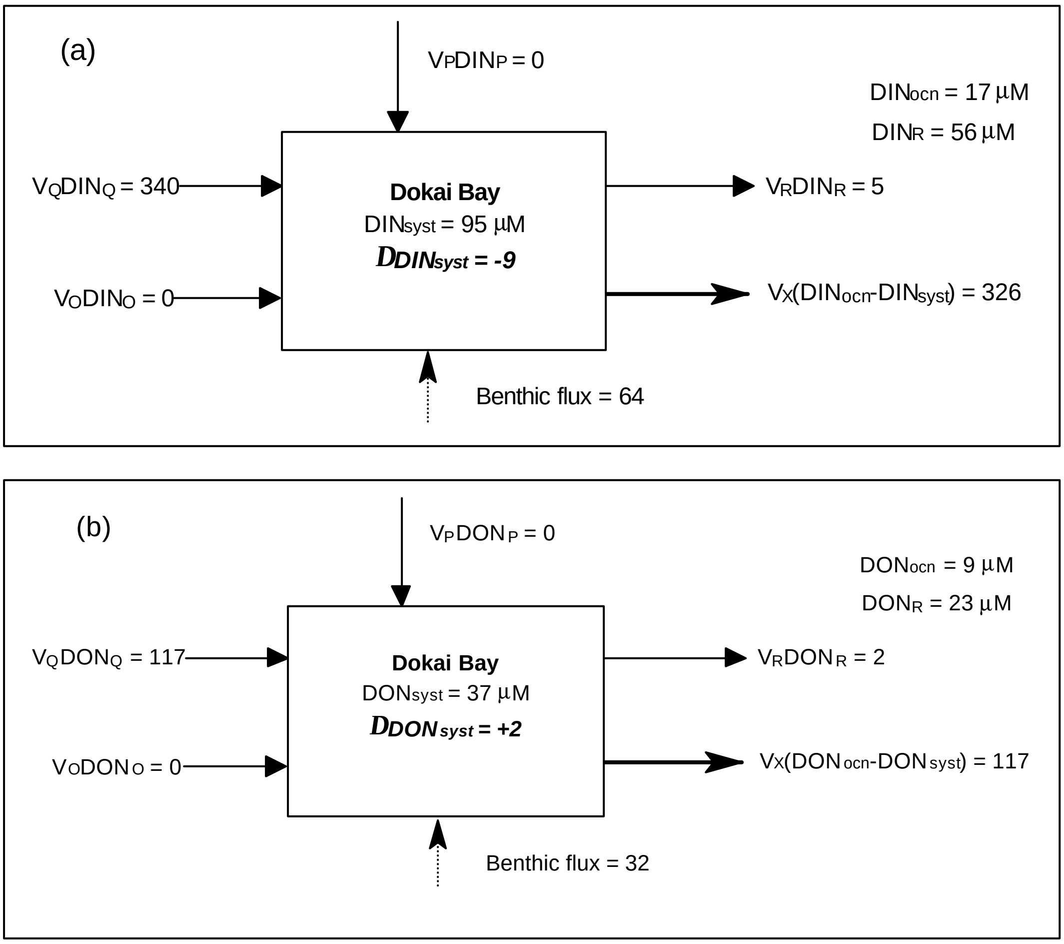

Figure 3.5. DIN (a) and DON (b) budgets for Dokai Bay. Flux in 10^3 mol d^{-1}.

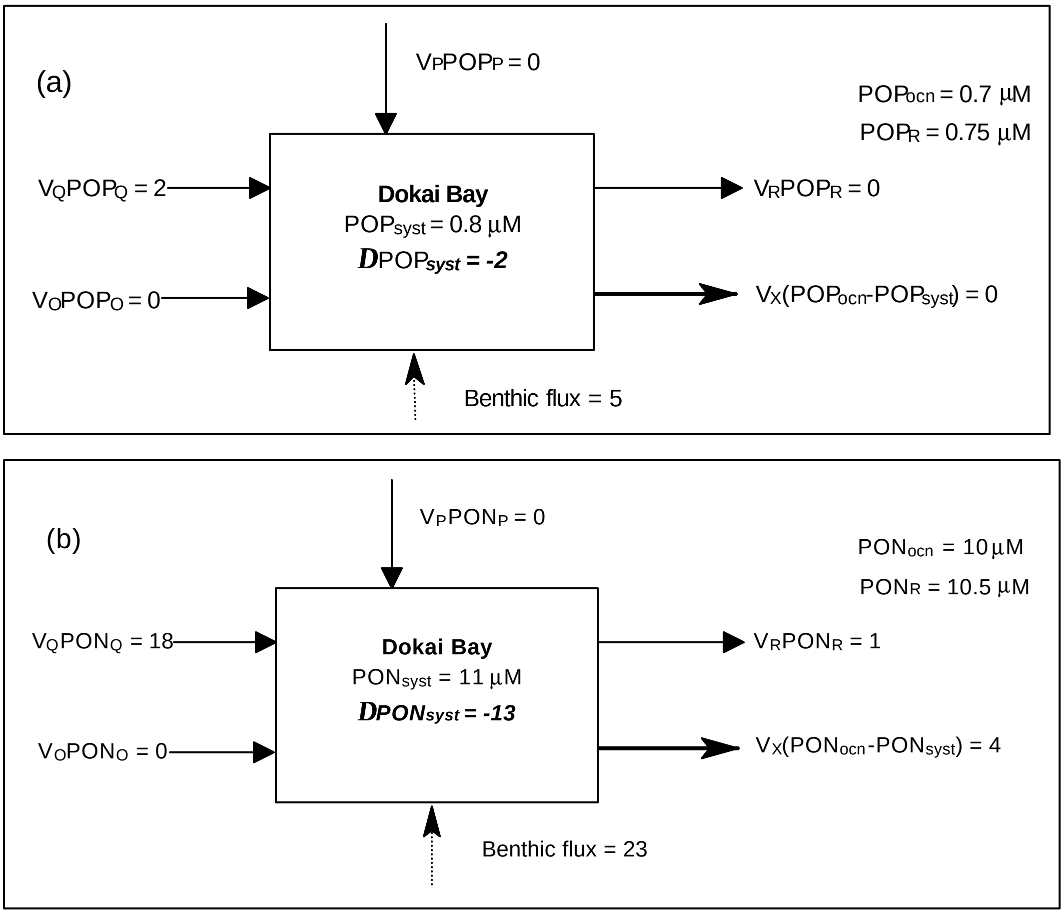

Figure 3.6. POP (a) and PON (b) budgets for Dokai Bay. Flux in 10^3 mol d^{-1}.

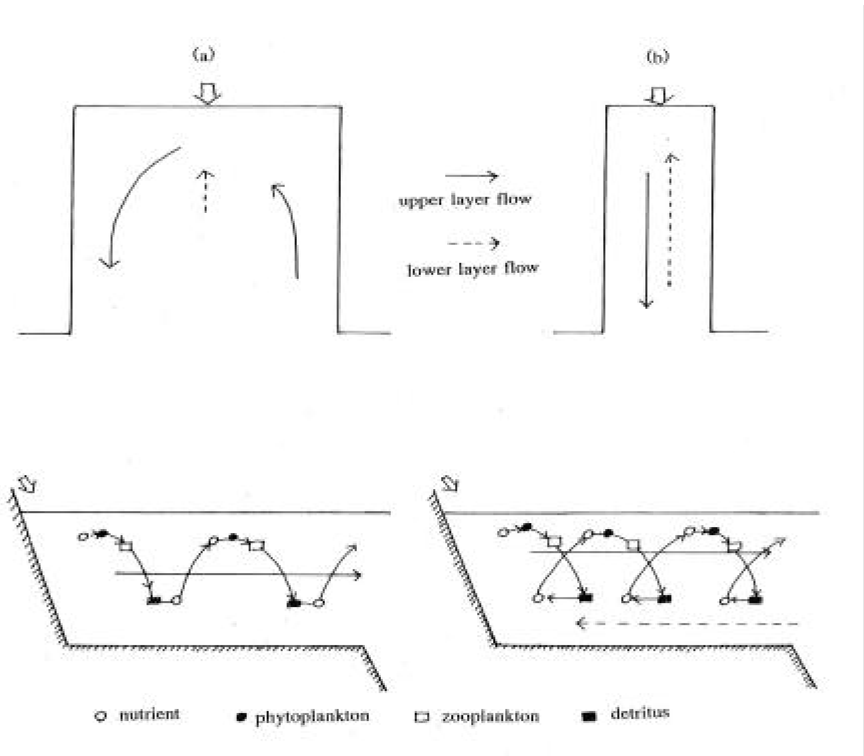

Figure 3.7. Schematic representation of transport of nitrogen in (a) a wide and shallow estuary and (b) a narrow and deep estuary.