Carrying Capacity Estimation of Marine Finfish Cage Culture at Pathew Bay, Chumphon Province Southern Thailand

Southeast Asian Fisheries Development Center
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Department of Fisheries
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FOREWORD

Under ASEAN-SEAFDEC Fisheries Consultative Group (FCG) Scheme, Thailand takes duty as the lead country among ASEAN member countries and the Training Department (TD) takes as lead department of SEAFDEC to implement coastal resources management program. This program is mainly supported by Japanese Trust Funds.

Under the coastal resource management program, TD and Department of Fisheries (DOF), Thailand collaborated in formulating and planning the collaborative coastal fisheries management project. An aim of the collaborative project is to promote and achieve sustainable use of resource utilization. TD and the DOF, Thailand agree to transfer essence of technologies, accumulated knowledge and lesson learned, which gain through the implementation of coastal fisheries management project to other SEAFDEC member countries through the SEAFDEC's information mechanism. This information may help ASEAN-SEAFDEC member countries to re-prior consider their own policies and formulate new direction for cost-effectiveness of coastal fisheries resource management plan and implementation.

Niwes Ruangpanit
Secretary-General

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Abstract

Carrying capacity estimation of marine finfish cage culture was carried out twice at Pathew Bay, Chumphon Province during 2002 - 2003. The concept of oxygen budget to meet the maximum carrying capacity was used in estimation. It found that the present cage culture in the bay is 950 fish (size 250 - 1000 gm/fish) at FC2. And the fish is 450 fish (size 250 - 450 gm/fish) at FC4. When the carrying capacity estimation is concern, the culture fish is under the carrying capacity at FC2 for seabass around 33.4% or 54,250 gm (body weight). Grouper is cultured over the carrying capacity 28.0% or 84,000 gm (body weight). At FC4, seabass is cultured over carrying capacity 67.1% or 135,900 gm (body weight) and grouper is cultured over carrying capacity 73.1% or 82,250 gm (body weight).

This result should show to fish farmers in order to understand the cultured condition. The number of cultured fish should be decreased to meet the carrying capacity.

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Background

Cage culture of fish is a method of growing fish in enclosed net while permitting water exchange and waste removal into the surrounding water. Fish densely stocked into cages require feed in adequate quantity and quality to promote fish growth. When feed is provided, water exchange is needed to bring oxygen into the cage and to remove waste products generated by the fish as a result of feeding.

In ecological terms, the carrying capacity of an ecosystem is the size of the population or community that can be supported indefinitely upon the available resources and services of that ecosystem. Carrying capacity of the fish case is usually expressed in terms of fish biomass per unit of water flow. The carrying capacity limits the weight of fish that can be cultured. Stocking so many fish that the carrying capacity is reached will result in increased stress, disease, and mortality, and reduced feed conversion efficiency, growth rate, and profit.

At times of high biomass and waste, water in the area surrounding the cage can become depleted of oxygen. This typically results when uneaten feeds and fish wastes accumulate under cages; and oxygen consumption by bacterial decomposition of the wastes and the fish in the cages lower dissolved oxygen to critical levels. Therefore, the dissolved oxygen plays a vital role on limiting growth and biomass in the finfish production.

Assumption

The management of maximum finfish production in coastal area can be carried out by adopted the concept of oxygen budget to meet the maximum carrying capacity of the net cages in the study area.

Objectives

1. To investigate the environmental parameters related to the oxygen supply and consumption in the net cage culture area.
2. To calculate the oxygen budget of the net cage culture area.
3. To estimate the carrying capacity of the net cage culture area.

Methodology

1. The investigation of environmental parameters related to the oxygen supply and consumption in the net cage culture area at Pathew Bay, Chumphon Province were taken in May and November, 2002 and January 2003 (**Fig.1**) . The methods are as follows:

   1.1 Measurement of oxygen supply (APHA, 1989)

   a) 24 h water flow was measured at several stations in and outside of the net cage area using current meter at different tidal cycles (High, Low and Neap tide) different season (3 times a year). The current vectors will be calculated.

   b) Current reduction of water passing though the net cages was measured at different location along the current flow direction in the study area. The measurement will be made in a single cage and a cluster of cages (2, 3 and 4 cage). The reduction coefficient (Slop of the graph of distance and current velocity) will be calculated.

   c) DO and temperature in the water at different locations in the culture area was measured at the same time of current measurement.

d) Oxygen diffusion at the water surface was calculated from the available function.

e) Oxygen production by photosynthesis was measured in the samples taken from in and outside net cage using dark and light BOD bottle incubation for about 4 hr. at the 30 cm depth. The measurement was made (3 time a year).

1.2 Measurement of oxygen demand (APHA, 1989)

a) Oxygen consumption and of the water was measured from the sample taken from in and outside net cage using dark and light BOD bottle incubation using the same data of 1.1 e).

b) Oxygen consumption of fish was estimated from the available function in term of body weight and temperature.

c) Sediment respiration was measured from the incubation of sediment core sampled in the net cage culture area.

2. Oxygen budget in the net cage culture area. This study would use the simple static oxygen budget model that calculation for several designed conditions which vary by the area of net cage and the density of fish. The environmental condition will be assumed to be constant in the same tidal current and season. The model is;

$$O_{in} = OC_{sed} + OC_{water} + OC_{fish} + O_{out}$$

O_{in} = Oxygen supply from the inflow water.

OC_{sed} = Oxygen consumption by sediment in the net cage.

OC_{water} = Oxygen consumption by water column in the net cage.

OC_{fish} = Oxygen consumption by all fish in the net cage.

O_{out} = Dissolved oxygen outflow from the net cage.

The dissolve oxygen supply (DO supply) and dissolve oxygen outflow is calculated as follows;

DO supply and DO outflow

= DO x area x depth x current velocity x current efficiency x 60 x 60 current

efficiency = current efficiency pass through net cage

= 0.18% (Srimukda and Nabhitabhata, 1995)

Oxygen consumption (OC) in water and sediment is also calculated as follows;

$$OC\ water\ (gO/h/cage) = \frac{OC \times area \times depth}{Mg/l/h}$$

$$OC\ sediment\ (gO/h/cage) = \frac{OC \times area}{m^2/h}$$

3. Carrying capacity of the finfish production in the net cage culture from the viewpoint of oxygen

availability.

$$\text{Maximum Carrying Capacity } (OC_{fish}) = O_{in} + OC_{sed} + OC_{water} + O_{out=3mg/l}$$

The maximum carrying capacity is calculated from the maximum number of fish (maximum OC_{fish}/OC of 1 kg fish) that contributed to the criteria of $O_{out=3mg/l}$ at the level DO 3 mg/l which is above the optimum for good growth of fish.

Results

1. The fish can be identified into two group FC2 and FC 4 and the current pattern in the bay during high and low tide is shown on **Fig.1**.

2. The measurement was done once in May 2002 as a pre-test. Then the second measurement was done in November 2002. The result shown in **Table 1**. The dissolve oxygen inflow into fish cage is around 5.47 - 5.62 mg/L during the high tide and around 3.76 - 3.91 mg/L during low tide. The dissolve oxygen outflow is around 4.36 - 4.84 mg/L during high tide and around 2.8 - 3.1 mg/L during low tide. The water current velocity is around 1.3 - 2.9 cm/sec. Oxygen consumption (OC) in water is around 0.025 mgO/L/h. And OC in sediment is around 173.1 - 332.7 mgO/m2/h (**Table 1**).

3. The third measurement was done in January 2003. The result is shown on **Table 2**. From this result, the dissolve oxygen (DO) available can be calculated as shown on **Table 3**. The DO available for fish consumption at FC2 during high tide is 453.7 gO/h/cage and 27.6 gO/h/cage during low tide. And DO available for fish consumption at FC4 during high tide is 1520.3 gO/h/cage and 672.1 gO/h/cage during low tide.

   The oxygen budget of water flow through fish cage estimate for high and low tide at FC2 and FC4 are shown on **Fig.2 and 3**.

4. The carrying capacity interm of DO available for fish in the cage, **Table 4** will show the carrying capacity estimated interm of DO available for fish in cage. For FC2 area, seabass is cultured under around 33.4% or 217 (867-650) fish (54,250 gm) during low tide. And grouper is cultured over around 28.0% or 84 (300-213) fish (84,000 gm) during low tide. It means that farmers can stock seabass more around 33.4% and need to decrease the number of grouper around 28.0%. For FC 4 area, both seabass and grouper are cultured over around 67.1% or 302 (450-148) fish (135,900 gm) and 73.1% or 329 (450-121) fish (82,250 gm), respectively. Due to the environmental management system, it should look at the estimation only during low tide.

Discussion

Rasenthal *et.al.* (1988) cited by Barg (1992) mentioned that the carrying capacity of a defined area refers in ecology to the potential maximum production a species or population can maintain in relation to (naturally) available food resources within the area. Barg (1992) stated that methods for estimating the carrying capacity of areas used for oyster and mussel farming are reviewed. Carrying capacity can be assessed by evaluating historical records of bivalve culture by measuring the availability of phytoplankton biomass or by undertaking more detailed studied e.g., of carbon and nitrogen flows through a bivalve culture unit interacting with the food web. Beveridge (1987) explained that the major consideration in the site selection process should be the carrying capacity of the site is the maximum level of production that a site might be expected to sustain.

Carrying capacity of finfish cage culture in this study is estimated by oxygen budget in finfish cage. The water exchange by tidal current is needed to bring oxygen into the cage and to remove waste products generated by the fish as a result of feeding. The maximum finfish production in coastal area can be carried out by adopted the concept of oxygen budget to meet the maximum carrying capacity of the net cages in the study area.

The result shows that the fish both seabass and grouper is cultured over carrying capacity at FC4 culture site. At FC2 culture site, seabass culture is under carrying capacity and grouper culture is cultured over carrying capacity. In term of sustainable management for this culture area, the biomass of fish should be managed along the carrying capacity estimation.

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Table 1 The results of finfish cage investigation in November 2002

No.	Tide	DO		cage dimension		water velocity (cm/sec)	Oxygen consumption	
		Inflow (mg/l)	Outflow (mg/l)	Area (m^2)	Depth (m)		water (mgO/l/h)	sediment ($mgO/m^2/h$)
FC2	High	5.47	4.84	16	2.8	2.9	0.025	332.7
	Low	3.76	3.1	16	1.3	1.3	0.025	332.7
FC4	High	5.62	4.36	16	2.75	2.9	0.025	173.1
	Low	3.91	2.8	16	1.4	1.3	0.025	173.1

Table 2 The results of finfish cage investigation in January 2003

No.	Tide	DO		cage dimension		water velocity (cm/sec)	Oxygen consumption	
		Inflow (mg/l)	Outflow (mg/l)	Area (m^2)	Depth (m)		water (mgO/l/h)	sediment ($mgO/m^2/h$)
FC2	High	5.24	3.4	16	2.7	0.9	0.150	211.1
	Low	4.1	3.76	16	1.2	0.8	0.150	211.1
FC4	High	5.85	4.4	16	2.6	3.9	0.025	188.8
	Low	5.02	2.57	16	1.4	1.9	0.025	188.8

Table 3 DO available for fish consumption during high and low tide of fish cage in Chumphon

No.	Tide	DO supply (gO/h/cage)	Oxygen consumption		DO outflow (gO/h/cage)	DO available for fish consumption (gO/h/cage)
			Water (gO/h/cage)	Sediment (gO/h/cage)		
FC2	High	1320	6.48	3.38	857	453.7
	Low	408	2.88	3.38	374	27.6
FC4	High	6150	1.04	3.02	4626	1520.3
	Low	1384	0.56	3.02	709	672.1

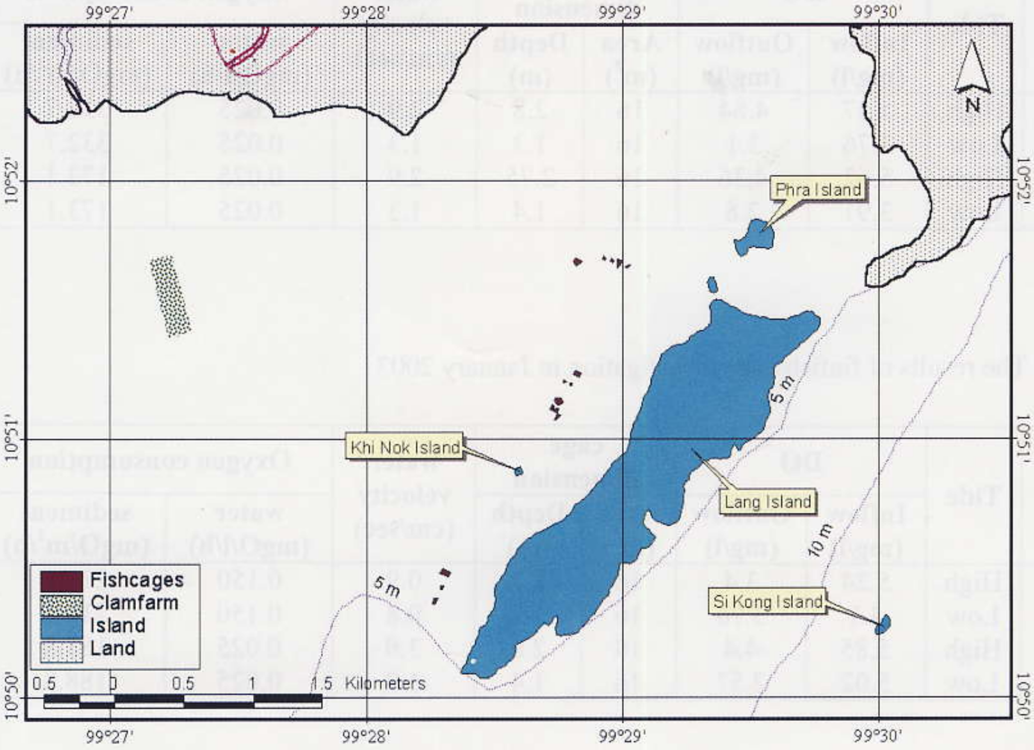
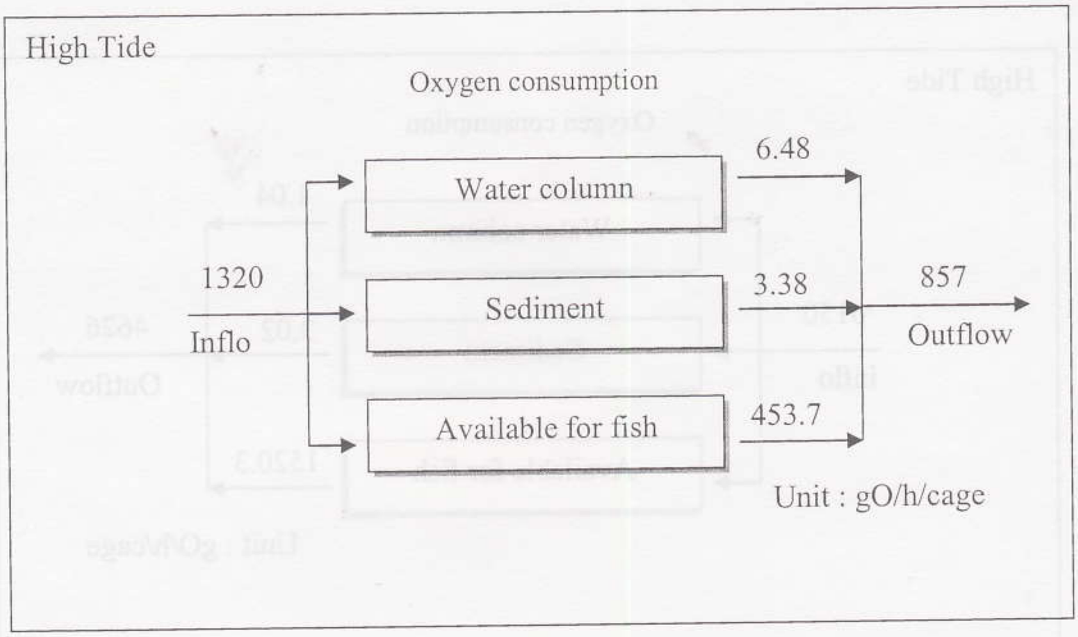


Fig 1. Location of fish cage and current pattern in Pathew bay



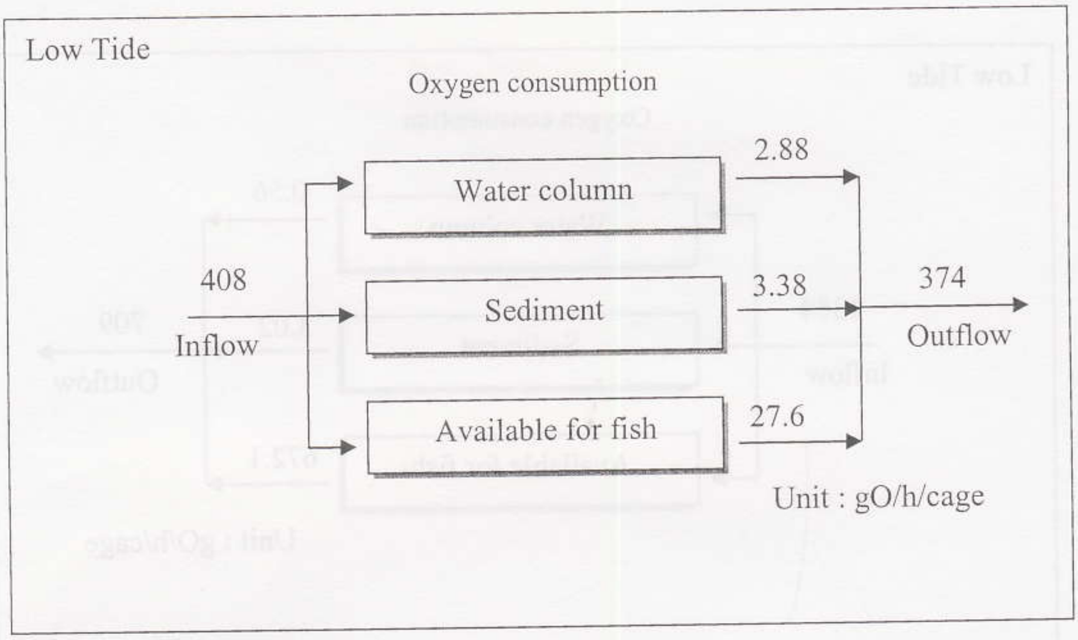


Fig 2. Oxygen budget of the water flow through the finfish cage estimate for high and low tide at area FC2

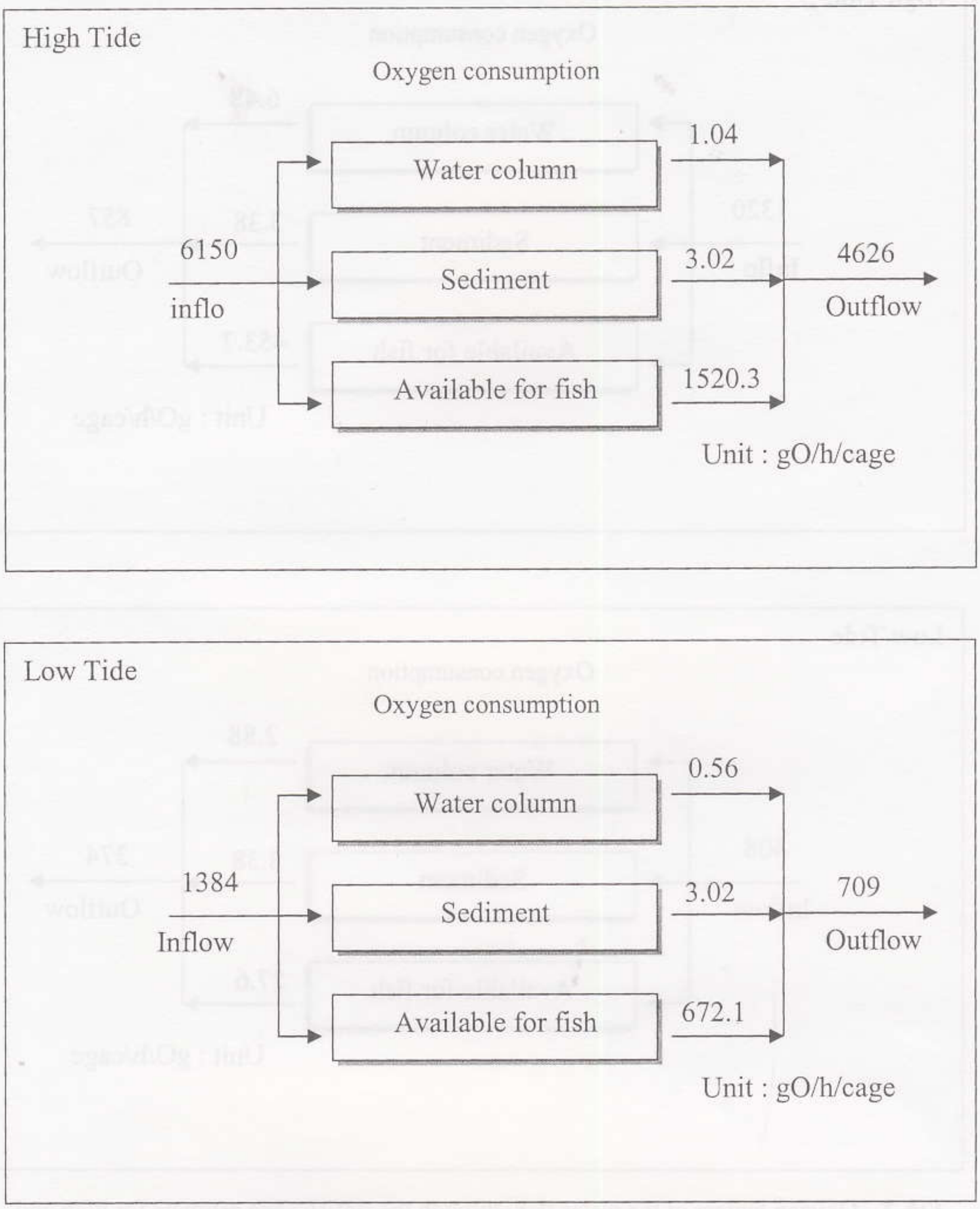
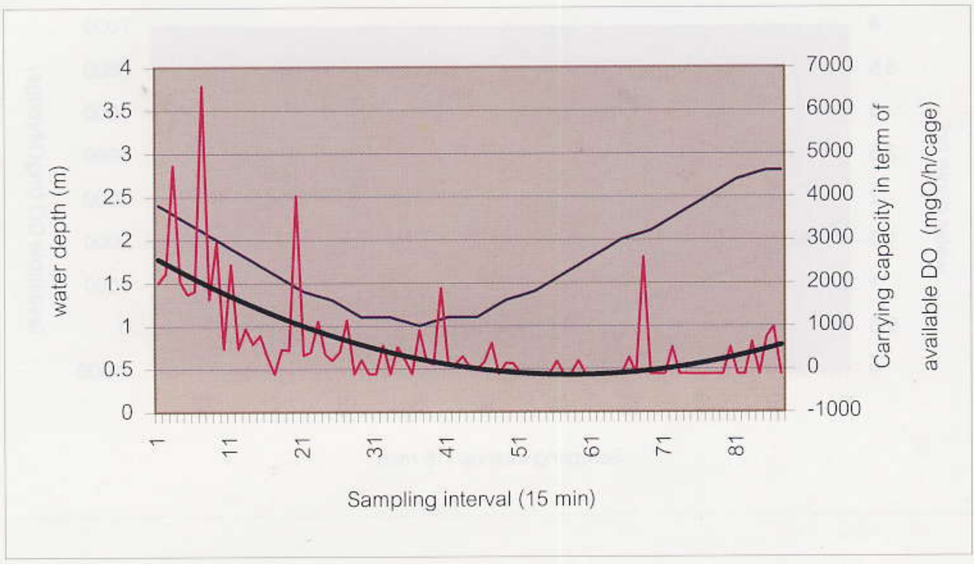
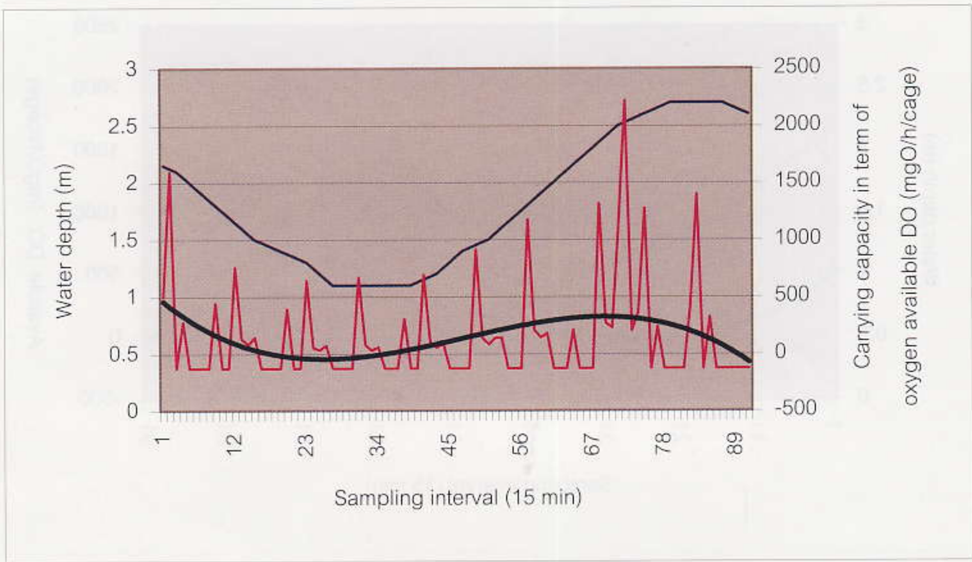


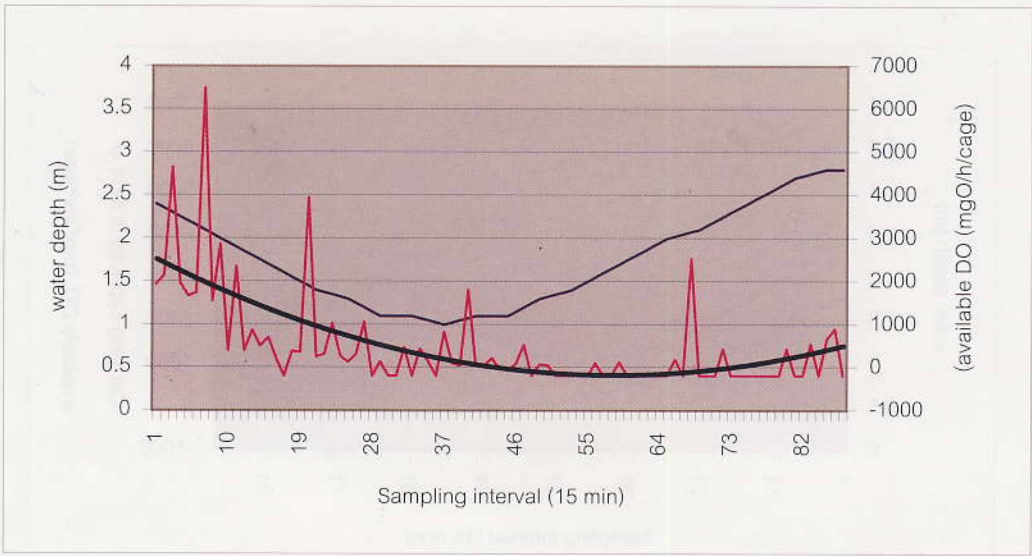
Fig 3. Oxygen budget of the water flow through the finfish cage estimate for high and low tide at area FC4

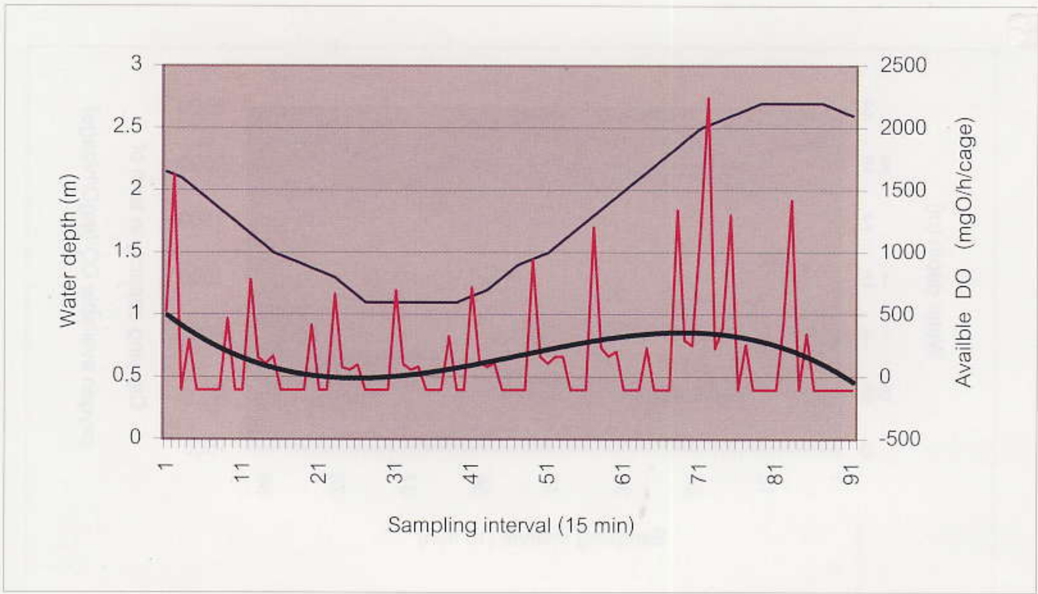




—— water depth
—— carrying capacity at DO = 3 mg/L
M carrying capacity at present.

Fig 4. The available DO for seabass cage culture estimated based on the condition of the outflow DO =3 mg/l in FC2 (top) at present stocking of 650 individual and 250g/ind. and FC4 (bottom) at the present stocking of 450 individual and 450g/ind.





—	water depth
—	carrying capacity at DO = 3 mg/L
M	carrying capacity at present.

Fig 5. The available DO for grouper cage culture estimated based on the condition of the outflow DO =3 mg/l in FC2 (top) at present stocking of 300 individual and 1000 g/ind. and FC4 (bottom) at the present stocking of 450 individual and 250g/ind.