Coastal aquaculture and shrimp farming in North Vietnam and environmental cost estimation

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This study aims to present an overview of coastal aquaculture, particularly of shrimp farming in North Vietnam, and to estimate environmental costs for coastal shrimp farming in Hai Phong City, as a case study. To achieve the study objectives, the main method employed was the economy model for environmental cost estimation. The study results show the continuous increase in area (10.5% to 31.8%) and yield (43,221.7 to 65,258.0 tons) of coastal aquaculture in all six provinces of North Vietnam. For seven years (1995–2001), the area of shrimp farming in Hai Phong City increased by 85%, while the yield increased by 348%. Estimation of environmental costs using an experimental model was developed for Hai Phong due to shrimp farming development with input contribution from over 60 farms in 2001–2003. Parameters input into the model are costs for each shrimp farm, including: Square Area (ha), Yield (kg), Shrimp price (Vietnamese dong (VND) kg^{-1}), Total replacement cost due to conversion of natural resources to shrimp farms (VND), Juvenile cost (VND), Food cost (VND), Culturing technical cost (VND), Fuel cost (VND), Chemical cost (VND), Medical cost (VND), Energy cost (VND), Disease prevention cost (VND), Water control cost (VND), Labour cost (VND). The developed model shows that the environmental cost will increase by 0.39% for every one unit of shrimp yield increased. Applying economic models (experimental models) to estimation of environmental costs of coastal shrimp farming and aquaculture generally allows promotion of some quantitative inputs to planning for sustainable aquaculture in North Vietnam.

Keywords: economic model, costs, Hai Phong, shrimp production

Introduction

Coastal aquaculture has dramatically developed in Asian countries, thanks mainly to the values of sea product export. Shrimp farming also brings high economic revenue to countries such as Vietnam, Thailand, China, Taiwan, etc. (Anon, 1993; Apub et al., 1983; Chanratchakoon et al., 1995; Hirano, 1993; Rabanal, 1974). The benefits of coastal aquaculture are obvious, but negative impacts on the environment are often ignored in developing countries. With over 3,260 km of coastline and a total area of about one million square kilometers of an exclusive economic zone, Vietnam possesses about 710,000 ha for coastal aquaculture and has a large potential for aquaculture expansion with over 3,000 islands and 112 river mouths (Lan, 2003). Aquaculture is also considered as the alternative to fishing, since over fishing has lowered productivity recently, and better livelihood for coastal communities to reduce poverty. Particularly, shrimp culture has contributed positively to the country's economy in terms of food security and economic growth. During 1999–2001 only, culturing shrimp export value in northern coastal region of Vietnam increased by about 100 percent each year (Ministry of Fisheries (MOFI),

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2001). Aquaculture areas, especially coastal shrimp farms, have been the subject of economic development projects, as well as studies related to the degradation of the environment (Dung, 2001; Hong, 1994; Lan, 2003; Thuoc, 1995). These studies have pointed out the negative impacts of coastal aquaculture, particularly shrimp farming on the environmental quality of water, sediment, habitats, etc. In North Vietnam, the main negative environmental issues of coastal aquaculture and shrimp farming in particular include narrowing the area of coastal wetlands (particularly mangroves), increasing turbidity in estuaries and coastal areas, unbalancing coastal erosion - accretion, degrading bottom sediment quality in aquaculture ponds, polluting coastal sediments and water, and penetrating of sea water to agricultural areas (Hong, 1994; Lan, 2003; Thuoc, 1995; Toan, 1999). Coastal farming is causing negative impacts on biological resources and ecosystems, including destroying and narrowing natural ecosystems, loss of habitat and nursery grounds, decreasing biodiversity, degrading intertidal biological resources and increasing the potentials of diseases in coastal waters (Hong, 1994; Lan, 2003; Thuoc, 1995; Toan, 1999). Other social impacts include enlarging the gap between the rich and the poor, changing local community livelihoods, conflicts of land use rights and water resource use among farmers and among economic sectors. For example, conflicts can arise between aquaculture and agriculture, transport, fisheries, mineral exploitation, industrial development and natural conservation (Lan, 2003). However, these studies do not properly answer the question of whether we need to develop aquaculture because it is economically beneficial, or reduce the aquaculture development because of its environmental impacts. Therefore, it is necessary to use economic instruments to evaluate the environmental costs of coastal aquaculture to quantitatively answer this question.

To date, there has not been any valuation made on environmental costs for coastal aquaculture in North Vietnam. To approach sustainable aquaculture, all environmental costs need to be included in total costs of coastal aquaculture. Hai Phong City area is selected as case study because shrimp farming is well developed and high yielding in the area and has occurred mainly in mangrove forests, a valuable ecosystem. Consequently, a large area of mangroves has been converted into shrimp farms. In the six year period from 1994 to 2000, 489.8 ha of mangroves were converted into shrimp farms (Lan, 2003). Four types of farming, based on shrimp culturing methods occur in the Hai Phong City area, including extensive, intensive, intensively extensive and semi-intensive farming, with the latter two being well developed and the focus of this study. This study aims to analyze previously published and unpublished data, providing an overview of the status of coastal aquaculture and shrimp farming in North Vietnam and estimating the environmental costs of these activities for the Hai Phong City area. This study also aims at contributing to the decision making process for sustainable aquaculture in Vietnam.

Materials and methods

Documents and data are collected from related works implemented in recent years (Dung, 2001; Hong, 1994; Lan, 2003; MOFI, 2001; Toan, 1999) in the study area, stretching from the northern area of Hai Phong - Quang Ninh to the southern area of Thanh Hoa province (Figure 1) and covering six provinces, including Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh and Thanh Hoa. Although coastal aquaculture and shrimp farming exist in all provinces, the most developed ones are Quang Ninh province and Hai Phong City.

Two SPOT satellite images of the Hai Phong coastal area were processed and analyzed using PCI software to extract information on the area extent of aquaculture, shrimp farming and mangroves in 1994 and 2000. These information layers were managed in ARCVIEW GIS software and were then used to evaluate changes in area by overlaying the layers of 1994 and 2000.

In order to estimate the environmental costs of coastal shrimp farming in the Hai Phong case study, an experimental model is developed based on the concept of direct approaches. The direct approach method is commonly applied using an experimental model, e.g. economic model for environmental cost estimation that is successfully applied in some countries (Department of Agricultural and Resource Economics, 1999). The experimental model requires variables (Table 1) with time sequences of data. However, in North Vietnam, these data are not available. Therefore, investigations and surveys were carried out in 2001–2003 at various shrimp farms to obtain sufficient data for the experimental model. Thirty four shrimp farms in Hai Phong provided input data for modeling environmental costs using experiment functions (Lan, 2005).

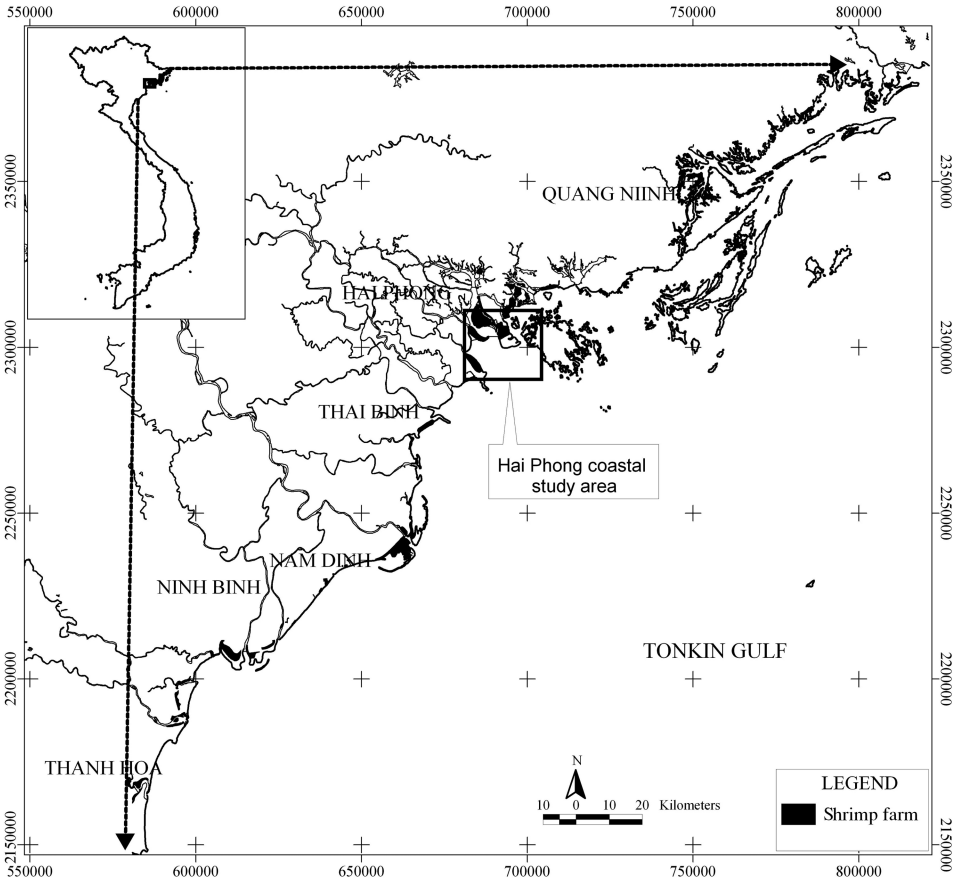

Figure 1. Study area and spatial distribution of shrimp farms in North Vietnam.

Results and discussion

Overview on coastal aquaculture and shrimp farming in North Vietnam

Coastal aquaculture in North Vietnam is developed mainly in intertidal areas, river mouths and shelters with a total surface area for aquaculture of 96,502 ha (MOFI, 2001), of which, shrimp farming is mostly developed in estuarine areas. Although a reasonable rate between total area and used area for aquaculture is not scientifically defined, the used area for aquaculture covers 50 to 60 percent of the total area, and the rest of the area is considered for

Table 1. Collected parameters for experimental model of coastal shrimp farming.

No.	Parameter–unit	No.	Parameter-unit
1	Square Area (Ld) – ha	8	Fuel cost (K4) - VND
2	Yield (Y) – kg	9	Chemical cost (K5) - VND
3	Shrimp price (P1) – VND kg^{-1}	10	Medical cost (K6) - VND
4	Total replacement cost (TRC) - VND	11	Energy cost (K7) - VND
5	Juvenile cost (K1) - VND	12	Disease prevention cost (D1) - VND
6	Food cost (K2) - VND	13	Water control cost (D2) - VND
7	Culturing technical cost (K3) - VND	14	Labour cost (La) - VND

VND: Vietnamese currency.

ecological purposes, e.g. nursery ground, environmental buffer, dyke protection, etc.

Over two decades aquaculture has been developed nationwide with 4 main types, including extensive, intensively extensive, semi-intensive and intensive types. Each is characterized by differing levels of investment, food, area of pond and productivity which are dependent on geographical scope.

In extensive culturing, aquaculture ponds are often from several hectares to hundreds of hectares. Juveniles and food are from nature. The productivity of this culturing is estimated from 50 kg ha^{-1} per harvest to 100 kg ha^{-1} per harvest (MOFI, 2001). Extensive culturing is based on the culturing with the partial addition of juveniles and food to ponds. The average density of juveniles contributed to a culturing pond ranges from 5 to 15 individuals per square meter (ind m^{-2}). The productivity of this culturing ranges from 250 kg ha^{-1} per harvest to 500 kg ha^{-1} per harvest (MOFI, 2001). Semi-intensive culturing has been developed since 1995 with small confined areas of 0.5 to 1 ha, and juvenile is completely supplied from hatcheries and man-made food. Juvenile shrimp density ranges from 20 to 30 ind m^{-2} and there are two harvests annually. Annual productivity ranges from 6 to 7 tons per hectare (tons ha^{-1}) (MOFI, 2001). Intensive culturing is developed with small ponds of 0.25 to 2.5 ha and juvenile are completely supplied from hatcheries and man-made food. With two harvests per year, annual productivity reaches 3.5 to 5 tons ha^{-1}. This culturing technique needs much technological investment and management for all aspects of the culturing process, including water supply and treatment, juvenile and food supply, disease monitoring, etc. Although intensive culturing was introduced to Vietnam in 1996, it is still not popular in North Vietnam.

There are five main groups of organisms cultured in the coastal area of North Vietnam, including fish, shrimp, seaweed, mud crabs and mollusks. Five fish species (*Epinephelus akaara, E. fuscoguttatus, E. brunneus and E. merra*), six shrimp species (*P. monodon, Macro branchium, Panulirus ornatus, P. homarus, P. longines* and *P. timsoni*), one mud crab species (*Scylla serrata*), two sea weed species (*Gracilaria verrucosa* and *G. blodgettii*) and three mollusk species (*Tegillarca granosa, Meretrix meretrix* and *Pinctata martensii*) are commonly cultured (MOFI, 2001).

Coastal aquaculture of the six provinces has been changing in yield and area. The area of coastal aquaculture in all six provinces increased in the period of 2001 to 2003. Quang Ninh had the lowest increase of coastal aquaculture area in this period (10.5 percent) and Thanh Hoa had the highest increase (31.8 percent). In other provinces, including Hai Phong, Thai Binh, Nam Dinh and Ninh Binh, the area increase ranged from 12.0 to 22.9 percent (MOFI, 2003).

The yield of coastal aquaculture in North Vietnam has been increasing. In 2001–2003, the total aquaculture yield for all six coastal provinces increased from 43,221.7 to 65,258.0 tons (MOFI, 2003) and the aquaculture yield of each coastal province continuously increased except for Quang Ninh and Thai Binh provinces where the yield of 2002 was higher than those of 2001 and 2003 (Figure 2). The reason for the 2003 yield decrease in the two provinces is not clear. In 2001–2003, Hai Phong had the yield increase from 9,821.8 to 20,709.0 tons; Nam Dinh increased from 9,949.0 to 12,338.0 tons; Ninh Binh increased from 441.2 to

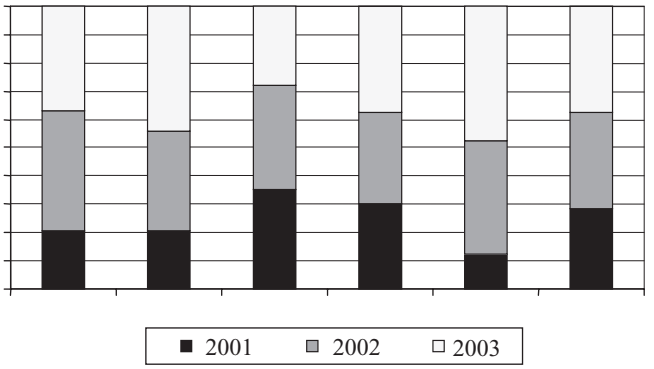

Figure 2. Coastal aquaculture yield in the six provinces of North Vietnam; Source: MOFI, 2003.

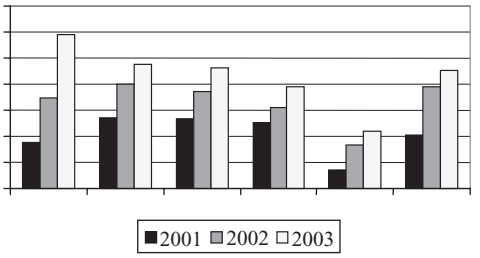

Figure 3. Shrimp yield in the six provinces of North Vietnam; Source: MOFI, 2003.

1679.0 tons, and Thanh Hoa -increased from 5,350.0 to 7,035.0 tons (MOFI, 2001).

In contribution to output value of coastal aquaculture, shrimp culturing takes the top place among groups of culturing species. In 2001, 2002 and 2003, the output values of coastal shrimp farming equaled 91 percent, 97 percent and 93 percent respectively, to the total output value of coastal aquaculture (MOFI, 2003). The yield of coastal shrimp farming in six provinces has been increased dramatically. From 2001 to 2003, the yields of 2003 ranged from approximately 1.5 to 3 times higher than those of 2001. Quang Ninh had the highest increase (about 3 times) in yield, followed by Ninh Binh, Thanh Hoa, Hai Phong, Thai Binh and Nam Dinh (Figure 3).

Coastal shrimp farming in Hai Phong

In the Hai Phong coastal area, aquaculture development, especially shrimp farming, is typical for North Vietnam in terms of cultured species, change in culturing area, change in production (Table 2) as well as environmental problems.

In the period of 1995 to 2001, the area and the yield of coastal shrimp farming in Hai Phong continuously increased. For seven years, the area increased by 85 percent while the yield much increased by 348 percent. From 1995 to 2003, the yield increased by 546 percent. Coastal shrimp culturing in Hai Phong has been developed by three main types of farming, including the extensive, the intensively extensive and the semi-intensive methods. The intensive method is not popular and small in area. However, most shrimp farms are developed in mangrove forests or close to mangroves (Hong, 1994; Lan, 2003).

The analysis of remotely sensed data acquired in 1994 and 2000 for the coastal area of Hai Phong (Table 3) indicates that the converted area from mangroves to shrimp farms was largest in An Hai District (196.9 ha) and smallest in Kien Thuy District (18.9 ha). The farm area in all districts during this period increased, while the mangrove area increased in only two districts of Cat Hai and Kien Thuy. The mangrove area in the district of An Hai in 2000 was larger than that in 1994 (846.9 ha compared to 688.0 ha). The increased area was planned replanting of mangrove implemented in this district. The total converted area increased by 81.6 percent from 1994 to 2000.

Coastal shrimp farming in Hai Phong is also facing environmental problems, such as water pollution in shrimp ponds due to concentrating wastes (solid, dissolved, toxic) using fertilizer and lime, and water waste. The concentration of nutrients is increasing from the beginning to the end of a harvest. In comparison with Vietnamese Environment Standards (VES) for coastal water, the concentration of nitrite (NO_2) of pond water (0.12 mg l^{-1} to 0.33mg l^{-1}) is higher than that of VES (0.01 mg l^{-1}). Hydrogen sulfide (H_2S) concentration (0.042 mg l^{-1}) is also higher than that of VES (0.005 mg l^{-1}) (Toan, 1999). This situation generates costs for polluted water treatment that are mentioned as TRC (Table 1) and computed into environmental costs.

Bottom sediments inside coastal shrimp farms are contaminated by components containing gases of H_2S and ammonia (NH_3) that can be emitted into the aqueous environment to cause the degradation of shrimp farm environments (Cu and Hoa, 1990). The concentrations of these gases range from 5 to 30 mg l^{-1} in the sediment and dissolved oxygen (DO) can be as low as 0 mg l^{-1} in the sediment (Cu and Hoa, 1990) inside coastal shrimp farms in Hai Phong.

Table 2. The area and yield of coastal shrimp culturing in Hai Phong from 1995–2005.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2005
Farm area (ha)	5,249	5,763	6,232	6,701	7,170	9,324	9,769	na	na	18,984
Yield (tons)	368	441	547	653	1,170	1,366	1,650	1,995	2,379	na

na: not available.
Source: Hai Phong Fisheries Department, 2001; MOFI, 2003.

Table 3. Change in area of shrimp farms and mangrove (ha) in coastal districts of Hai Phong.

Districts	Area in 1994		Area in 2000		Converted area from mangrove to shrimp farms
	Farm	Mangrove	Farm	Mangrove	
Cat Hai	1,145.6	936.1	1,796.6	821.5	196.9
An Hai	1,098.7	688.0	1,618.1	846.9	274.0
Kien Thuy	1.1	36.3	72.5	9.6	18.9
Total	2,245.4	1,660.4	3,487.2	1,678.0	489.8

Source: Lan, 2003.

Although in Hai Phong, water pollution in aquaculture ponds has occurred, the coastal waters outside aquaculture area is still good since shrimp farms cover less than 20 percent of the total potential area for aquaculture. As shrimp farms are sparse in coastal districts, wastes from culturing are a relatively insignificant cause of coastal water pollution.

Estimation of environmental costs from coastal shrimp farming

The environmental impacts from coastal shrimp farming can be evaluated monetarily using an economic model. Unfortunately, there is no available data for aquaculture environmental cost valuation for North Vietnam. As such, coastal shrimp farming in Hai Phong was selected as a case study for estimation of environmental cost. Due to the limited of data, the average cost per productive unit is used. This approach overcomes the difficulties of differences in shrimp farms, sample size and lack of data.

The estimation of environmental costs of coastal shrimp farming in Hai Phong was calculated using the method of least squares and the Cobb-Douglas function (Lan, 2003). The data were collected from existing sources and from surveys around Hai Phong from 2001 to 2003 and the environmental cost model for Hai Phong is:

$$\text{Log(TEC)} = 0.53 + 0.39\log(\text{Y}) + 0.18\log(\text{K2})$$

where, TEC = total environmental cost from shrimp farming, Y = farmed shrimp yield, K2 = food.

Estimation of Ld, TRC, K5, K6 and D1 (see Table 1) were computed into the variable for yield (Y). Other collected parameters (Table 1) were for production and social cost estimations. The experimental mode for log(TEC) is then dependent on two variables: yield (Y) and food (K2). The simplified experimental model is applied to the environmental cost increase for two years of shrimp production in Hai Phong. With this model, decision makers and planners can estimate fees for environmental protection when they plan to develop more shrimp farming. Also, farmers can be assisted to estimate how much they have to pay for environmental protection. From this model the environmental cost for Hai Phong area can be estimated that with an increase of 1 percent in shrimp production output, the environmental cost will increase by 0.39 percent (Lan, 2005).

Table 4 provides an example of applying this environmental cost model for the period from 1997 to 2001, with the average export price of Vietnamese shrimp of \$US15 kg^{-1}, the environmental costs that should be added to the total production costs ranged from \$750,000 to \$5,500,000 US because of shrimp production development.

There are two limitations of the data used in the time series analysis in developing this environmental cost model. Firstly, some environmental impacts are not monetarily quantified in the inputs (e.g. impacts on ecosystems and social impacts), and secondly, reliability in this model will increase with incorporation of more samples.

As an initial reference point, the results of this model can be used for sustainable development planning of shrimp production in Vietnam to 2010. As planned in the national program for aquaculture in the period of 1999–2010 issued by the Ministry of Fisheries of Vietnam, the yield of coastal shrimp production in the whole country in 2010 will be 360,000 tons with the value of US\$1.4 billion (MOFI, 1999). Assuming that this value is not included in the environmental protection expenses, applying the model with shrimp production in 2003 of 237,880 tons valued at approximately \$US12,500,000 (MOFI, 2003); and shrimp production increases by 51.34 percent between 2003

Table 4. Environmental cost due to shrimp production increase in Hai Phong.

Year	Shrimp yield (ton)	Commodity value using average price of $US15 kg^{-1}	Increase in shrimp yield by year (%)	Environmental cost increase by production increase (%)	Environmental cost added to total production costs (US dollars)
1997	547	8,205,000			
1998	653	9,795,000	19.38	7.67	75,166
1999	1,170	17,550,000	79.17	31.35	550,236
2000	1,366	20,490,000	16.75	6.63	135,927
2001	1,650	24,750,000	20.79	8.23	203,769

Source: Lan, 2005.

and 2010, then the environmental cost increases by 20.02 percent. As a whole, the total cost for shrimp production will require a further $7,207,688 US to cover environmental costs (environmental taxes, environmental fees, etc.). This means that if 360,000 tons of shrimp are produced in 2010, the total value would be $1.4 billion US plus about $280 million US for environmental costs. This estimation demonstrates an application of the model for planning with environmental protection integration in case of coastal shrimp farming throughout Vietnam is similar to the activities in Hai Phong City.

Conclusions

Coastal shrimp farming in North Vietnam has recently increased in area, production and culturing methods. This has brought great economic benefits: in particular poverty alleviation of coastal communities, but has also had negative impacts on natural resources and the environment, particularly converting valuable mangrove ecosystems into shrimp farms and polluting shrimp farm water. This has negatively affected the fisheries sector due to the reduction of shrimp production after 3 to 5 years farming because of the degradation of shrimp farm environments. To estimate the environmental costs for developing strategies and making policies for sustainable fisheries is urgently required, but difficult to implement. To combat this, the application of experimental economic models as applied in other countries is feasible and most appropriate in Vietnam's current status. The modeling environmental costs of coastal shrimp farming in the Hai Phong area show that with an increase of one percent in shrimp production output, the environmental cost will increase by 0.39 percent. Based on these results, it is recommended that environmental costs should be included with total production costs when shrimp farming is planned. In coming years these costs could include environmental fees, and taxes with the rate generated using the experimental economic model used to estimate for Hai Phong City.

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