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# Impact assessment of dredging on fish eggs and larvae: A case study in Caotan, South China

Z F Yang<sup>1</sup>, D Chen<sup>1,3</sup>, and B P Xiao<sup>2</sup>

<sup>1</sup>College of Harbor, Coastal and Offshore Engineering, Hohai University, Nanjing 210098, China <sup>2</sup>Zhanjiang Marine Fisheries Bureau, Zhanjiang 524039, China

<sup>3</sup>E-mail: yzf8@vip.163.com

Abstract Dredging can lead to an increase in suspended sediment concentration, which poses a threat to the survival of fish eggs and larvae. To assess the impact of dredging on fish eggs and larvae, Caotan Fishing Port in south China was chosen as a case in this paper. The threat to the survival of fish eggs and larvae, i.e. the increased suspended sediment concentrations, is identified through analyzing pollution sources in dredging operations; the number and species of fish eggs and larvae were obtained through on-site investigations; the concentration and influence range of suspended sediments are calculated by pollutant diffusion equations; the loss of fish eggs and larvae caused by suspended sediment during dredging is evaluated according to Technical Regulations for the Impact Assessment of Construction Projects on Marine Biological Resources (SC/T 9110-2007) in this paper. It can be preliminarily concluded that the suspended sediments produced during dredging and backfilling have an impact on the survival of fish eggs and larvae, and will reduce their quantity. Currently, loss analysis methods are based on empirical formulas, and more accurate quantitative analysis needs to be further studied.

#### **1. Introduction**

Dredging is especially important in improving harbor facilities, and it is required to remove a large quantity of dredged materials each year. A major method of disposing dredged materials is ocean dumping which, however, has been limited by the London Protocol 1996 and the London Convention 1972 [1]. Therefore, one of the major disposal methods of dredging materials, since the establishment of these agreements, has been putting dredged materials in landfills that can process the material.

Dredging is one of the intensive engineering activities which occur in the coastal regions where many marine species live [2-5]. To reduce the impact of dredging on the marine environment, an in-depth understanding of how dredging affects marine habitats is required. Until now, studies of the effects of dredging on marine flora, benthic infauna, and the seabed are well conducted [6-8]. However, there are few detailed and in-depth studies on the impacts on fish eggs and larvae.

Dredging can lead to an increase in suspended sediment concentration, which poses a threat to the survival of fish eggs and larvae. The impacts of increased suspended sediment concentrations are highly variable from species to species, relating to the sediment characteristics [9]. High suspended sediment concentrations, directly or indirectly, do damage

to fish eggs and larvae, which mainly manifests as termination of early pregnancy; lower hatching rate; gill damage in fish [10]; a ferocious anoxia which may result in death of creatures in the water; reduced survival rate and increased intracorporal residual toxicants due to changed physiological mechanism of fish eggs, destroyed self-renewal mechanism of fish stocks, and destroyed spawning grounds and feeding grounds of fish, as a result of secondary pollution of suspended hazardous substances. The hatchability of fish eggs decreases dramatically due to the covering effect of suspended sediment. The inhibited growth of phytoplankton caused by increased concentration of suspended sediment and decreased transparency of water color leads to the decrease of primary productivity in the sea area, thus affecting the abundance of zooplankton feeding on phytoplankton, the feeding rate fish larvae, and ultimately the development of fish larvae.

Caotan Fishing Port Project is taken as an example in this paper, and according to the investigation data of fishery resources in the evaluated waters, referring to the relevant assessment methods in *Technical Regulations for the Impact Assessment of Construction Projects on Marine Biological Resources* (SC/T 9110-2007), and combining the existing research results, the loss of fish eggs and larvae caused by suspended sediment during the project is evaluated, with a view to providing some reference for the protection of fishery resources.

#### 2. Study area

Caotan Fishing Port, located on the west coast of Leizhou Peninsula and the northeastern end of Beibuwan Bay, Guangdong Province, in the east longitude of 109°46'14", north latitude of 21°46'14" is taken as the study area. According to the dredging capacity and dredging mode of different types of dredgers, the cutter suction dredger will be used for dredging operations in the channel waters of the harbour basin. Part of the dredged mud produced by dredging operations is used for sea reclamation behind the project, and the remaining dredged mud is reclaimed to the land area of the harbor.

A total of 12 ecological survey stations in the waters near Caotan Fishing Port (the longitude and latitude of the stations are shown in Table 1, four fishery resources survey sections (Y1-Y4), with station positions and sections shown in Figure 1, were set up to investigate fish eggs and larvae in the sea area near the project.

			e			
No.	А	В	С	D	Е	F
Latitude	21°20′55.41″	21°21′00.96″	21°21′23.76″	21°16′34.32″	21° 6′55.80″	21°17′43.93″
Longitude	109°45′18.97″	109°42′08.46″	109°38′15.36″	109°45′26.12″	109°42′11.19″	109°37′39.74″
No.	G	Н	J	K	L	М
Latitude	21°12′30.92″	21°13′31.00″	21°14′45.57″	21°09′35.32″	21°10′15.14″	21°11′22.91″
Longitude	109°44′38.76″	109°41′03.06″	109°36′46.29″	109°41′20.77″	109°38′20.49″	109°35′03.53″

**Table 1.** Investigation station coordinates.

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Figure 1. Site map of ecological survey station.

#### 2.1. Survey method of fish eggs and larvae

A large plankton net (80 cm in diameter, 270 cm in length and 0.505 mm in aperture) was dragged horizontally and 1 net was sampled at each station, being dragged for 10 minutes with an average towing speed of 1.5 kn. Before the cast of the net, whether the net fittings were damaged, the bottom pipe was in normal condition and the flowmeter was in good condition had been examined; the flow rate of the flowmeter had been recorded and the speed of the investigating vessel had been reduced to about 1.5 kn before the cast of the net. After put into the water with the opening of the net completely under water, the net was dragged continuously for 10 minutes before it was pulled up and the flow rate of the flowmeter was recorded again.

The net was raised to an appropriate height, and the outer surface of the net clothes was washed repeatedly from top to bottom with flushing equipment to make the samples adhering to the net gather in the net bottom pipe; the specimen was then put into the sample bottle after taken from the net bottom pipe, and the screen silk cover was washed repeatedly with ear wash ball until all the remaining samples were in the sample bottle. 5% formalin solution by the product volume was then fixed in to preserve the samples and the species composition and quantity of eggs and larvae were identified and calculated with a microscope.

The density of eggs and larvae is calculated by dividing the total number of individuals captured by horizontal trawl by the amount of filtered water.

$$V = N/(S \times L)$$
(1)

where, V is the distribution density of eggs and larvae (ind/m<sup>3</sup>); N is the number of larvae per net( ind); S is the net opening area; L is the trawling distance.

#### 2.2. Modelling for tidal current and sediment

Tidal movement may be controlled according to the following equations:

(1) Continuity equation:

$$\frac{\partial \zeta}{\partial t} + \frac{\partial [(h+\zeta)u]}{\partial x} + \frac{\partial [(h+\zeta)v]}{\partial y} = 0$$
(2)

(2) Momentum equation in x direction:

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} - fv = -g \frac{\partial \zeta}{\partial x} - \frac{gu\sqrt{u^2 + v^2}}{c^2(h+\zeta)} + \frac{\partial}{\partial x} \left(N_x \frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y} \left(N_y \frac{\partial u}{\partial y}\right)$$
(3)

(3) Momentum equation in y direction:

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + fu = -g\frac{\partial \zeta}{\partial y} - \frac{gv\sqrt{u^2 + v^2}}{c^2(h+\zeta)} + \frac{\partial}{\partial x}(N_x\frac{\partial v}{\partial x}) + \frac{\partial}{\partial y}(N_y\frac{\partial v}{\partial y})$$
(4)

where.

T——the time (S);

x, y——the coordinates of the rectangular coordinate system where the original point o is placed in a certain horizontal base plane;

*u*, *v*—the components of the velocity vector  $\vec{V}$  in x and y directions (m/s);

 $\zeta$ —the water level relative to xoy coordinate plane (m); *h*—the water depth relative to xoy coordinate plane (m);

 $N_x$ ,  $N_y$ —the flow turbulence viscosity coefficients in x and y directions (m<sup>2</sup>/s);

f——the coriolis parameters;

g——the gravity acceleration  $(m/s^2)$ ;

c—the chezy coefficient.

Transport and diffusion of the suspended sediment may be controlled according to the following equation:

$$\frac{\partial s}{\partial t} + u \frac{\partial s}{\partial x} + v \frac{\partial s}{\partial y} = \frac{\partial}{\partial x} (D_x \frac{\partial s}{\partial x}) + \frac{\partial}{\partial y} (D_y \frac{\partial s}{\partial y}) + \frac{F_s}{h+\zeta}$$
(5)

where, T——the time (S); x, y——the coordinates of the rectangular coordinate system where the original point o is placed in a certain horizontal base plane; u, v-----the components of the velocity vector in x and y directions (m/s); D<sub>x</sub>, D<sub>y</sub>----the turbulent fluctuation diffusion coefficients of the suspended sediment in x and y directions  $(m^2/s)$ ; F<sub>s</sub>——the sediment source function or sediment scouring and silting function  $(kg/(m^2 \cdot s)); \zeta$ ——the water level relative to xoy coordinate plane (m); h——the water depth relative to xoy coordinate plane (m).

#### 2.3. Analysis of pollution in the construction process

The dredging operation mode of cutter suction dredgers is as follows: the cutter is positioned to start the dredging operation, and then after being sucked through the pump in the mud chamber, the sediment was transported to the reclamation site, and after the backfill area is settled, the surface low-content mud water is discharged into the sea through the overflow mouth. The construction process of cutter suction dredger is shown in Figure 2. According to Figure 2, the environmental impact of dredging and land backfilling mainly occurs in the process of dredging and hydraulic fill.

(1) In the dredging operation, the sediment was suspended due to the agitation of the cutter, resulting in turbidity of the water and declined water quality, which had an impact on plankton and benthos. Suspended sediments were the main pollutant in dredging construction.

(2) The turbidity of water and declined water quality in the waters near the overflow port caused by the suspended matter discharged from the overflow port will have an impact on fish eggs and larvae. The main pollutant was the suspended sediment.



Figure 2. Pollution source analysis of dredging and reclamation.

In order to predict and calculate the effects of sediment suspension on marine water quality and ecological environment during sea-filling, two representative construction sites were

selected as the construction points for suspended material prediction and calculation. They are: 1 # construction site (marked with  $\bullet 1$ , as shown in Figure 3) located at the dredging construction point of Typhoon shelter of the harbour pond, and 2 # construction site (marked with  $\bullet 2$ , as shown in Figure 3) located at the overflow port of the newly built wharf reclamation area.



Figure 3. Location of dredging sites and adjacent marine functional areas.

#### 3. Result and discussion

#### 3.1. Fish eggs and larvae

The survey was conducted in the early spring, the early stage of fish spawning. Among the 12 samples collected, 13 species of larvae and fish eggs were found. The name list is as follows:

- 1. Stolephorus sp. (larvae)
- 2. Sardinella sp. (larvae)
- 3. Syngnathus acus (larvae)
- 4. Mugilidae (fish eggs and larvae)
- 5. Sillago sihama (larvae)
- 6. Cynoglossidae (fish eggs)
- 7. Sparus microcephalus (larvae)
- 8. Sparidae (fish eggs)
- 9. Sciaenidae (larvae)
- 10. Callionymus richardsoni (larvae)
- 11. Gobiidae (larvae)
- 12. Scorpaenidae (fish eggs)
- 13. Leiognathus sp. (larvae)

Among the founded fish eggs, the number of Sparidae eggs was the dominant one, accounting for 66.2% of the total. In addition, Mugilidae and Cynoglossidaes eggs also appeared, with the number accounting for 15.6% and 5.5% of the total, respectively. Among the larval species, the number of Stolephorus sp. dominated, accounting for 63.4% of the total, followed by Sparus macrocephalus (14%), Sardinella sp. (7%), and Syngnathus acus (5.4%)., and the remaining species occurred sporadically.

In this survey, 726 ind eggs and 196 ind larvae were collected. The density of fish eggs and larvae is shown in Table 2. The average density of eggs was 633 ind/1000  $\text{m}^3$  and that of larvae was 176 ind/1000  $\text{m}^3$ .

Fish eggs appeared in all stations, but the number was small. The stations with relatively large number were M, G and D, with the density of 1554 ind/1000  $m^3$ , 1542 ind/1000  $m^3$  and 1179 ind/1000  $m^3$ , respectively. The main species are Sparidae and Mugilidae.

The larvae also appeared in all stations, and Station F has the largest number, with a density of 624 ind/1000  $\text{m}^3$ , followed by stations C, B and D, with a density of 272 ind/1000  $\text{m}^3$ , 227 ind/1000  $\text{m}^3$  and 193 ind/1000  $\text{m}^3$ . The main species were Stolephorus sp. and Sparidae.

Station		А	В	С	D	Е	F
Density	Fish eggs	23	385	454	1179	295	170
	larvae	46	227	272	193	137	624
Station		G	Н	J	K	L	М
Station	Fish eggs	G 1542	Н 544	J 34	K 975	L 442	M 1554

**Table 2.** Fish eggs and larvae density in Caotan sea area of Suixi (ind/1000 m<sup>3</sup>).

#### 3.2 Prediction and calculation of suspended sediment concentration

The construction of dredging (1 # construction site) and reclamation (2 # construction site) were carried out simultaneously, during which period the maximum value-added concentration appears at 1 # construction site within a diurnal tide cycle of the spring tide. The values of increased suspended sediment concentrations (mg/l) and the corresponding area (km<sup>2</sup>) are shown in Table 3.The largest concentration value of 365.73 mg/l appears in 1# construction site.

**Table 3.** Values of increased suspended sediment concentrations (mg/l) and the corresponding area (km<sup>2</sup>).

Contour line value	150	100	50	20	10
Area	0.04	0.05	0.16	0.26	0.49

## 3.3. Effects of dredging and backfilling on fish eggs and larvae

According to the Technical Regulations for the Impact Assessment of Construction Projects on Marine Biological Resources (SC/T9110-2007), the one-time damage assessment of biological resources is calculated by the following formula:

$$W_i = \sum_{j=1}^n D_{ij} \times S_j \times K_{ij} \tag{6}$$

where,

W<sub>i</sub> - The amount of damage to the Type *i* biological resources (kg, ind);

 $D_{i,J}$  - The density of the Type *i* biological resources in the Type *j* increased concentration area of a pollutant, the unit is kg/km<sup>3</sup> and ind/km<sup>3</sup>;

 $S_i$  - The area of Type j increased concentration zone of a pollutant, the unit is km<sup>2</sup>;

 $K_{ij}$  - The loss rate of Type i biological resources in the increased concentration area of a pollutant, in units: %;

n - Total number of increased concentration divisions of a pollutant.

The calculation shows that the loss quantity of fish eggs is 95 503, and loss quantity of larvae is 26 607, as shown in Table 4:

Increased suspended sediment concentration (mg/l)	Superstandar d multiple (Bi)	Area(m <sup>2</sup> )	Loss rate (%)	Loss quantity of fish eggs	Loss quantity of larvae(ind)
10~40	$1 \le B_i \le 4$	300000	10	28491	7938
40~90	$4 \leq B_i \leq 9$	127200	30	36241	10096
≥90	$B_i \ge 9$	64800	50	30770	8573
Total		_	_	95503	26607

IOP Conf. Series: Earth and Environmental Science **351** (2019) 012035 doi:10.1088/1755-1315/351/1/012035 **Table 4** Loss of eggs and larvae.

#### 4. Conclusion

The results of this study are only applicable to the preliminary prediction before the implementation of the project. In the actual construction process, the species and quantity of marine organisms should be monitored, and the construction plan should be adjusted according to the monitoring results.

From the above analysis, it can be preliminarily concluded that the suspended sediments produced during dredging and backfilling have an impact on the survival of fish eggs and larvae, and will reduce their quantity. Currently, loss analysis methods are based on empirical formulas, and more accurate quantitative analysis needs to be further studied. Especially, the validation test should be properly carried out to corroborate their findings

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