Technology of Assessing Marine Fishery Loss Caused by Oil Spills

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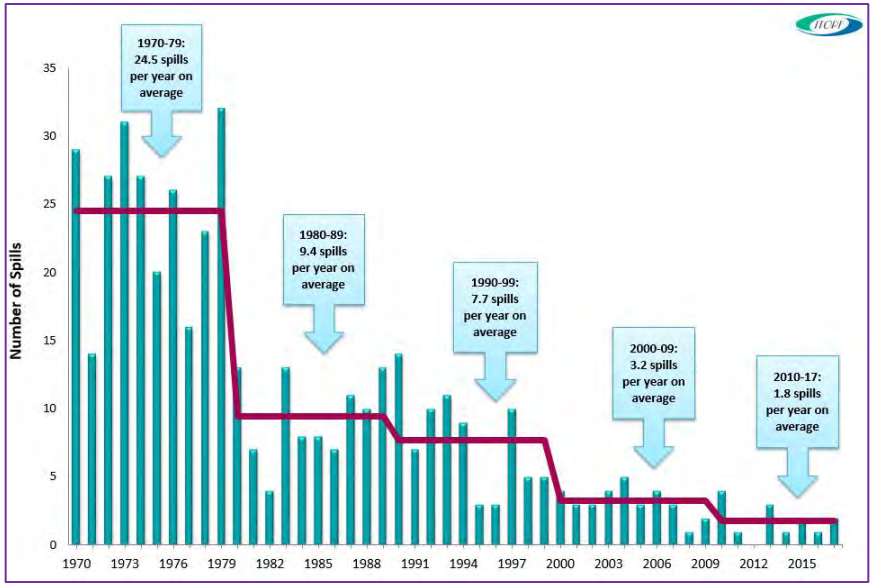
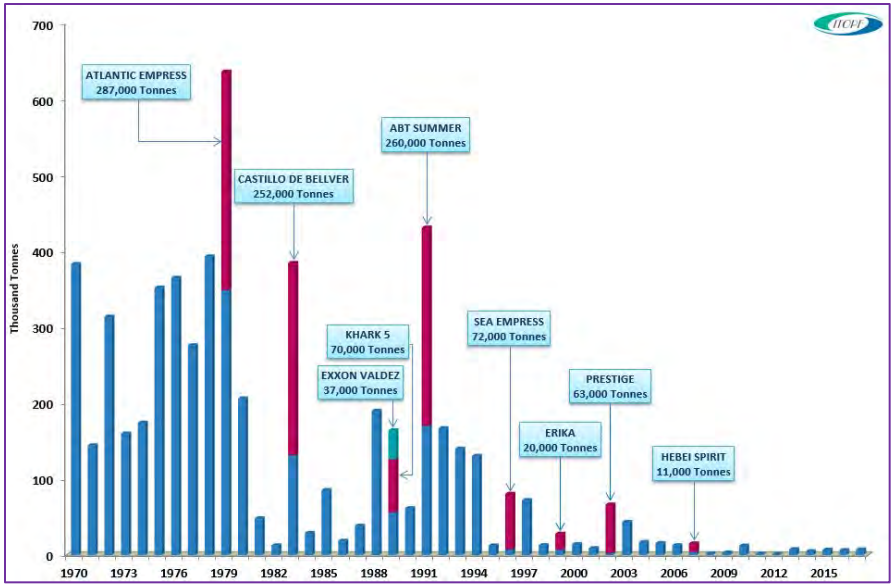
An introduction——What?

According to International Tanker Owners Pollution Federation(ITOPF)'s statistics, the worldwide offshore oil spills occurred in the amount of more than 5000 tons of large-scale accidents nearly 200, most of which from shipping accidents, accounting for more than 70%. Oil spills occupies 0.5% of global oil production .



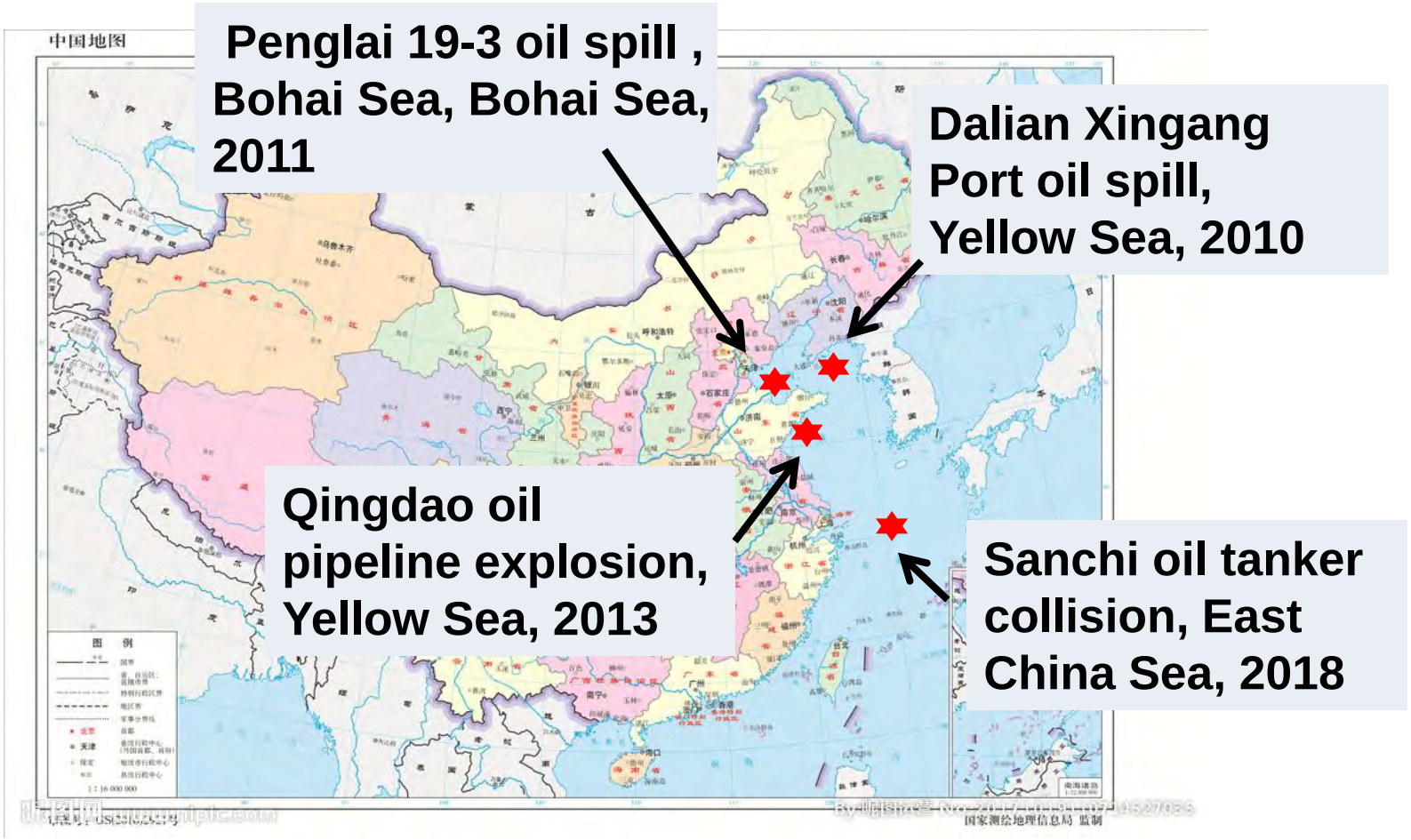


An introduction——What?

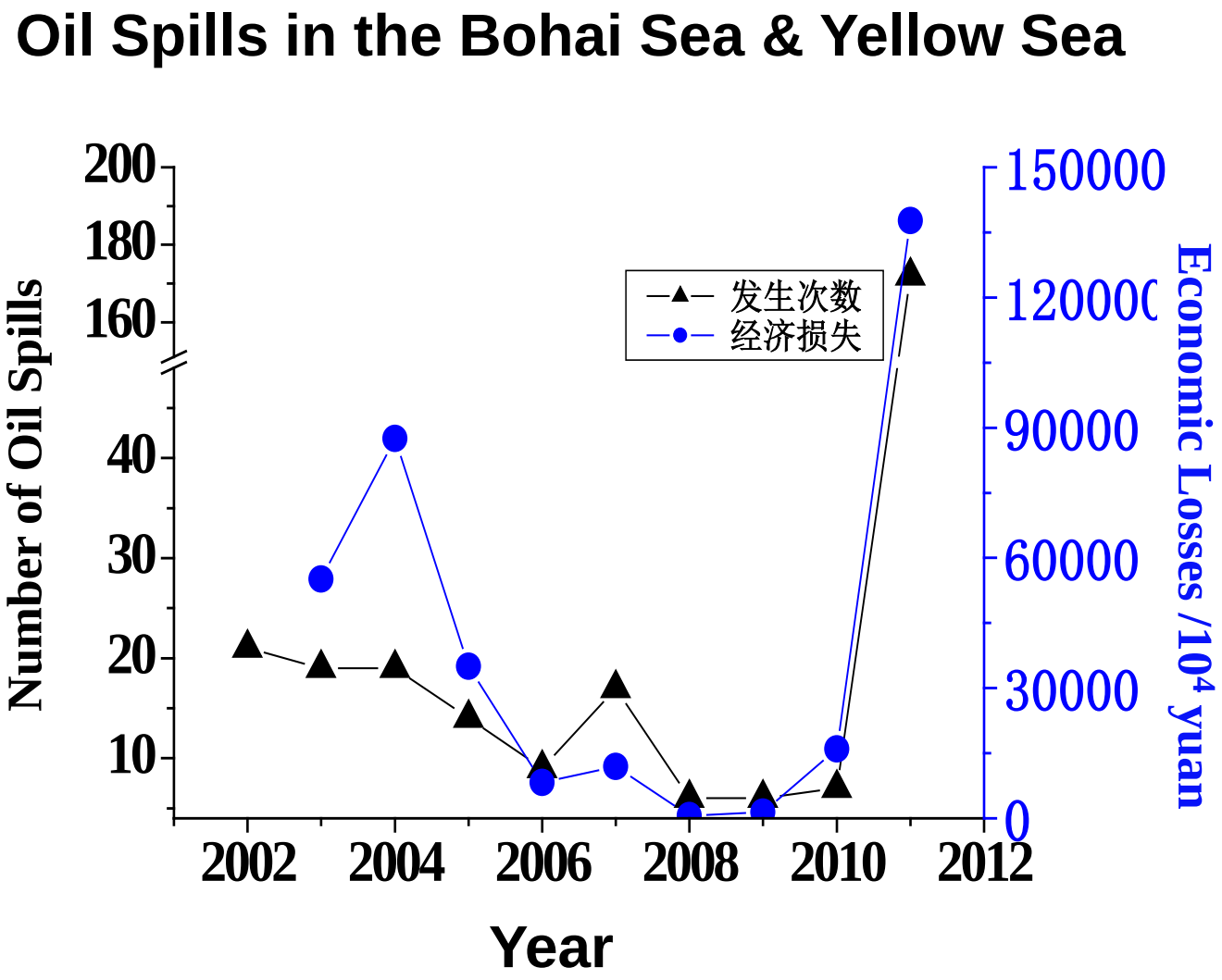
What Year?	Where did it occur?	What tanker was it?	How much oil did it spill (tons)?
1983	The Persian Gulf	Nowruz Oil Field	600,000
1983	South Africa	Castillo De Belluer	250,000
1988	The Monongahela River	Storage Tank	3,800,000
1993	Off The Shetland Islands	Braer	26,000,000
1996	Off SW Wales	Sea Empress	18,000,000
2001	Galapagos Islands	Jessica	240,000
2010	Gulf of Mexico	Deepwater Horizon	680,000
2011	Bohai Sea	Penglai 19-3 Oil Field	7070
2018	East China Sea	Sanchi Oil Tanker	Spilling or burning >100,000 tonnes

An introduction——What?

Some serious marine oil spills in China in recent years.



An introduction——What?



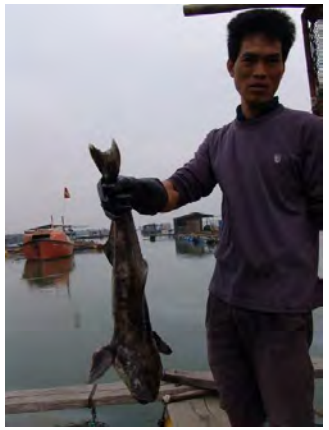
Effects of oil spills——Why?

On environments

Spilling oil contains toxic products like aroma compounds and poses a serious threat to the marine environments .

On society

Oil spills cause huge economic losses, some fishermen loose their jobs, and hotels and restaurants face to be closed economic losses.



On politics

Oil spills cause critics that accuse the government for inadequate rescue sometimes. In 201, President Obama of USA was judged on how he would deal with the crisis.

Effects of oil spills——Why?

- **On marine life**

Birds die from oil spills if their feathers are covered in oil.

Some marine mammals and reptiles, such as dolphins, whales and turtles are very vulnerable to oil spills because they have to be able to surface to breathe and the reptiles also need to leave the water to breed. The layer of oil makes surfacing difficult and the animals drown.

The effects on fisheries include two aspects. One is the natural fisheries resources including swing animals, benthos, fish eggs and larvae, and so on in the open sea area. The other is on aquaculture.

Assessing fishery damages ——How?

Scientific?

(objective& reasonable)

Social?

(Fair & just)

Damage Assessment Standard

(Data:Spilling, Oil, Fishes……)

Assessing fishery damages ——How?

National Standard:

calculating method on the economic loss of fishery pollution accidents

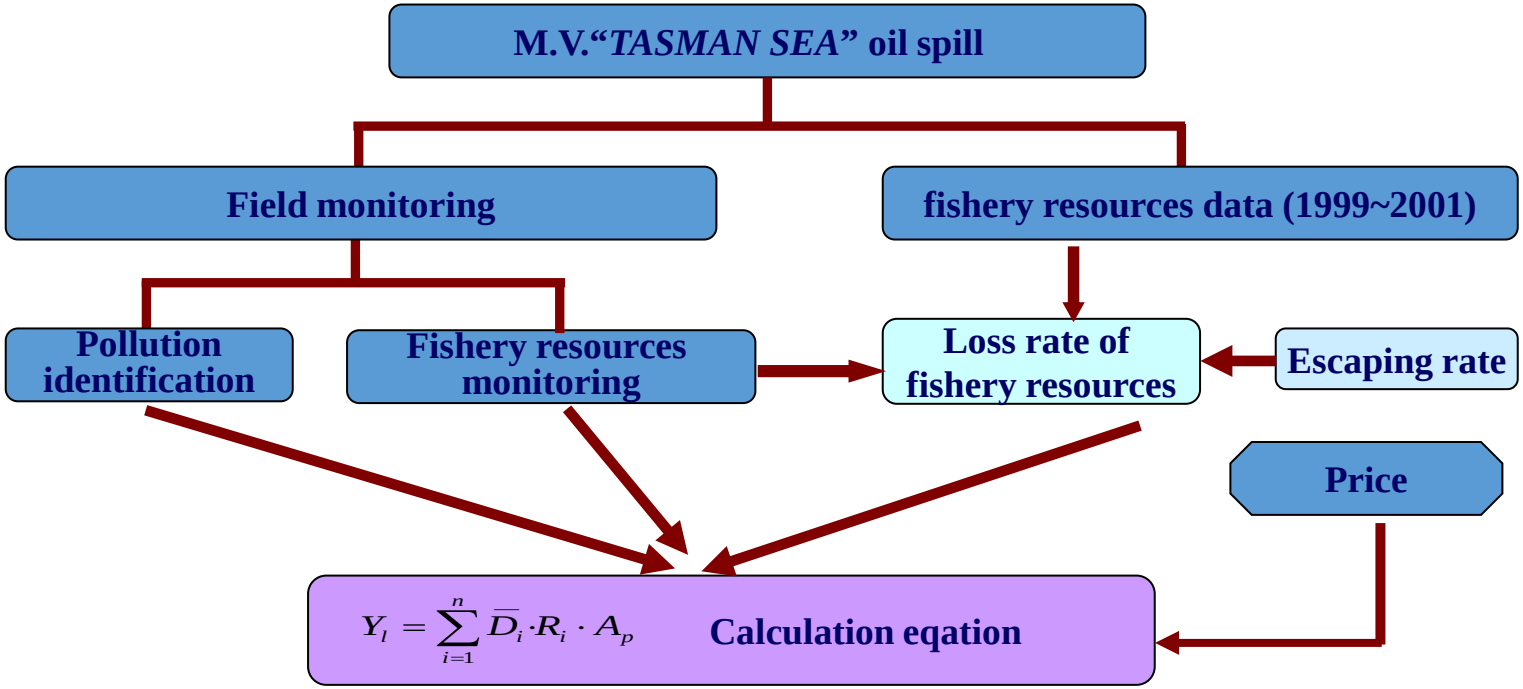
First edition, 2008

Second edition, 2018

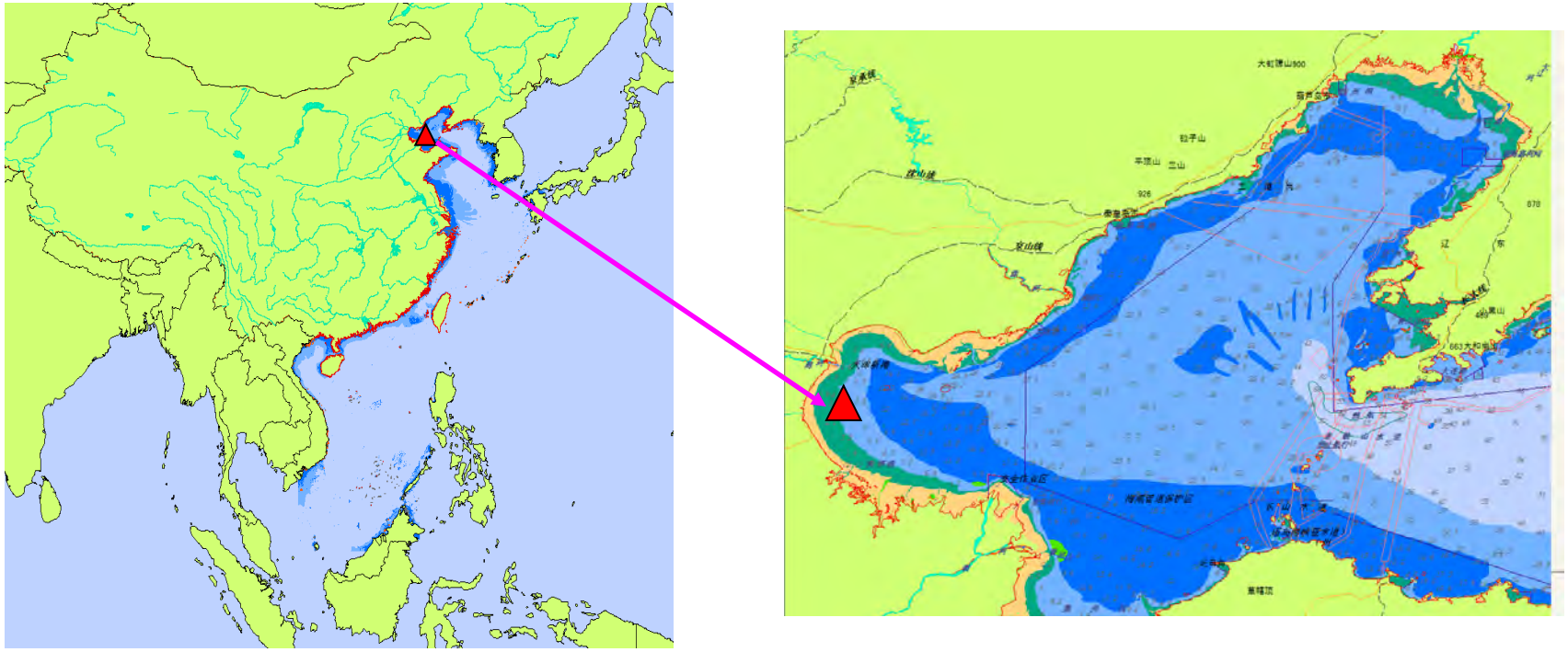
Assessing fishery damages ——Case studies

- **Direct Calculation Method**

  - ✓ **Field monitoring data**
  - ✓ **Historical data**



Assessing fishery damages ——Case studies



Incident Site

In 2002 November, Malta oil tanker "Tasman Sea" and China coastal ship "shunkai No. 1" collided in the Bohai bay of China, The third starboard cabin of "Tasman Sea" ruptured, and lots of oil spilled into the sea.

Assessing fishery damages ——Case studies

Environmental monitoring data & fishery resources data

The monitoring data showed that the polluted area (concentration of oil more than 0.25 mg/L) was about 690km^2.

Year	Density of fish	Dominant species
1999	344.02	*Chaeturichthys stigmatias Richardson*, *Pampus argenteus*,perch, anchovy, *Pseudosciaena polyactis Bleeker*, *Setipinna taty* , *Scomberomorus niphonius*, *Areliscus semilaevis*
2000	328.80	perch, *Chaeturichthys stigmatias Richardson*, *Pampus argenteus*, anchovy, *Pseudosciaena polyactis Bleeker*, Barracuda
2001	377.15	perch, *Chaeturichthy stigmatias Richardson*, *Scomberomorus niphonius*, *Setipinna taty*, Pampus argenteus, *Pseudosciaena polyactis Bleeker*, anchovy, Barracuda

Average density of fish: 349.99kg/km^2

Assessing fishery damages ——Case studies

The table below showed the density and dominant species of crustacean in survey area in November of 1999~2001, and the average density was 88.45 kg/km^2

Year	Density of crustacean	Dominant species
1999	88.33	*Oratosquilla oratoria*, *Trachypenaeus curvirostris*, *Portunus trituberculatus*, *Charybdis japonica*, *Alpheusjaponicus Miers*
2000	88.27	*Oratosquilla oratoria*, *Portunus trituberculatus*, *Trachypenaeus curvirostris*, *Charybdis japonica*, *Alpheusjaponicus Miers*
2001	88.74	*Oratosquilla oratoria*, *Portunus trituberculatus*, *Trachypenaeus curvirostris*, *Charybdis japonica*, *Alpheusjaponicus Miers*
Average density of crustacean : 88.45 kg/km^2		

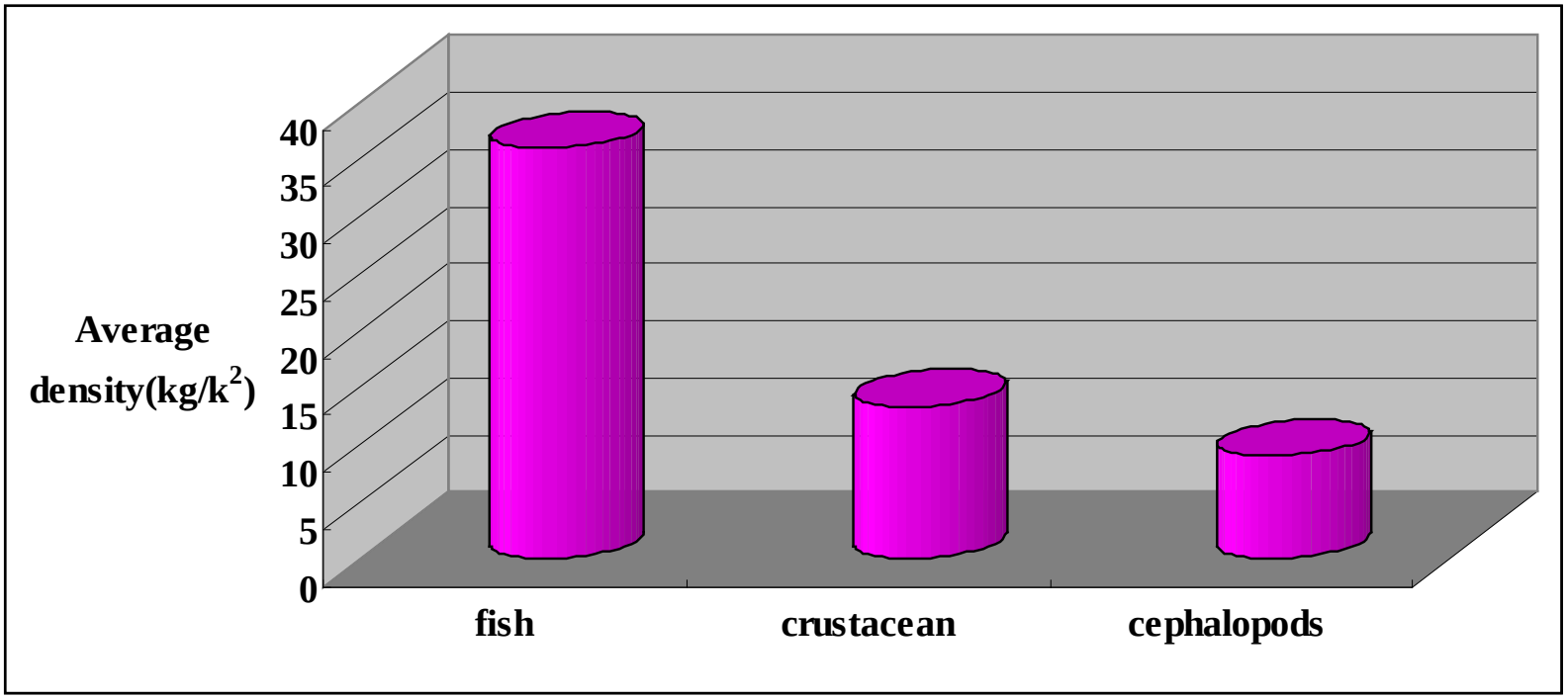
Assessing fishery damages ——Case studies

This table showed the density and dominant species of cephalopods in survey area in November of 1999~2001, and the average density was 36.35kg/km^2

Year	Density of Cephalopods	Dominant species
1999	33.96	*Octopus ocellatus* , *Octopus variabilis*
2000	38.49	*Octopus ocellatus* , *Octopus variabilis*
2001	36.59	*Octopus ocellatus* , *Octopus variabilis*
Average density of cephalopods: 36.35kg/km^2		

Assessing fishery damages ——Case studies

The survey data showed that the average densities of fish, crustacean, and cephalopods were 35.86 kg/km^2, 13.28 kg/km^2 and 8.91 kg/km^2 , respectively.



Assessing fishery damages ——Case studies

Calculating method

Loss Rate(%)= (Contemporaneous Average Resource Density (1999~2001)- Average Resource Density (After pollution))/ Contemporaneous Average Resource Density (1999~2001)- Escaping Rate

Fishery Resources Loss（kg）= Average Resource Density (3 years before pollution)× Loss Rate ×Pollution Area

Direct Economic Loss of Natural Fishery Resources （yuan）= Local Aquatic Products Price（yuan/kg）× Fishery Resources Loss （kg）

Assessing fishery damages ——Case studies

Calculating results

The calculating results are shown in the following table. The economic losses of fish, crustacean and cephalopods were 3.02, 1.12 and 0.32 million yuan, respectively, and the total loss was 4.46 million yuan.

Fish resources		Loss Rate(%)=	Fishery Resources Loss（kg）	Economic Loss (Thousand Yuan)
Fish	High Value	63.0	50,373	3,020
	Normal Value	60.3	70,645	
	Low Value	52.5	23,304	
crustacean		75.1	44,922	1,123
cephalopods		65.5	16,428	319

Assessing fishery damages ——Case studies

- **comparison method**

  - ✓ **Field monitoring data**
  - ✓ **No historical data**

$$Y_l = \sum_{i=1}^{n} \left[\overline{D}_{ui} \cdot - \overline{D}_{pi} \right] \cdot A_p$$

where

Y_l **is fishery resources loss (unit: kg or ind.)**

$\overline{D}_{ui}$ **is average fishery resources density of control area**

$\overline{D}_{pi}$ **is average fishery resources density of pollution area**

A_p **is pollution area**

"comparison method" was used when there no contemporaneous historical data of fishery resources within 5 years before accident, so we could choose a control area and assess the economic losses of fishery resources according to the comparison between the control area and the pollution area. The control area must be not far from the pollution area.

Assessing fishery damages ——Case studies

On July 8, 2004, Chinese ship "Jin Gan 6" collided with a foreign vessel in the Bohai Strait. The collision caused the sinking of "Jin Gan 6" and a large amount of oil spilled and about 311.5 km^2 seawaters were seriously polluted.

The “comparison method” was successfully used in estimating the economic losses of fishery resources in this accident.

Assessing fishery damages ——Case studies

- **Fixed sampling station capture method**

The "fixed sampling station capture method" was used for calculating the loss of benthos or sea bottom culture organisms in the polluted area, and the fishery resources could not be captured by trawling. The losses are calculated with equations as follows:

Calculation of fishery resources loss

$$Y_l = \sum_{i=1}^{n} S_i \cdot \overline{D}_{fi} \cdot A_p \cdot R_i \cdot (1 - R_{si})$$

where

Y_l **is fishery resources loss**

$\overline{D}_{fi}$ **is density of fishery resource *i***

A_p **is polluted area**

S_i **is weight of fishery resource *i***

R_i **is loss rate of fishery resource *i***

R_{si} **is natural mortality rate of fishery resource *i***

Calculation of Loss Rate:

$$R = \frac{N_l}{N_t} \cdot 100\%$$

where

R **is loss rate**

N_l **is number of lost organism**

N_t **is total number of captured organism**

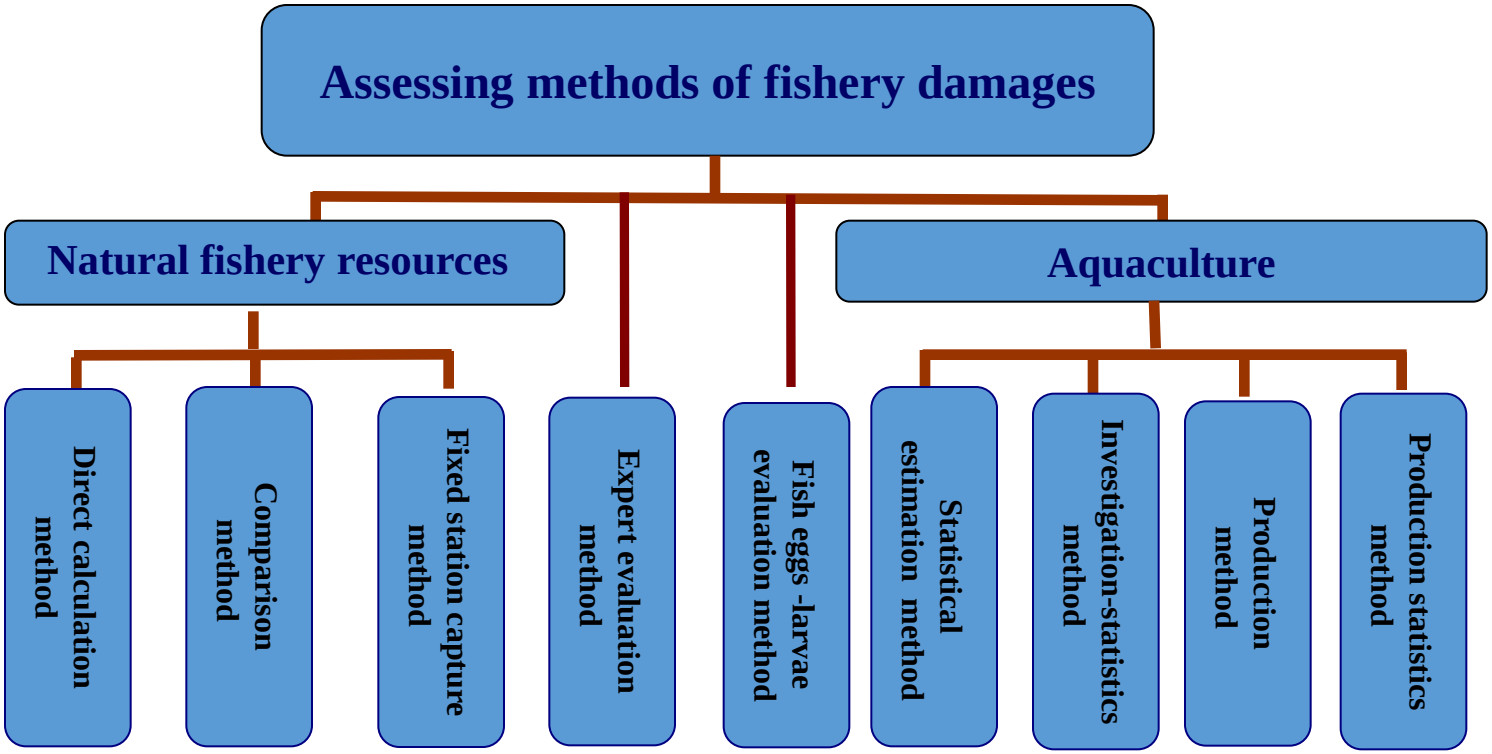
Assessing fishery damages ——Case studies

On July 2, 2005, Chinese ship “Qiandaoyou 1" collided with a Malaysia ship near the Dalian seawaters. The collision caused amounts of oil spilled in the sea and the pollution of *Haliotis discus hannai* seed field.

The “fixed sampling station capture method” was first used in calculating the economic losses of precious benthos such as abalone, sea cucumber and sea urchin.

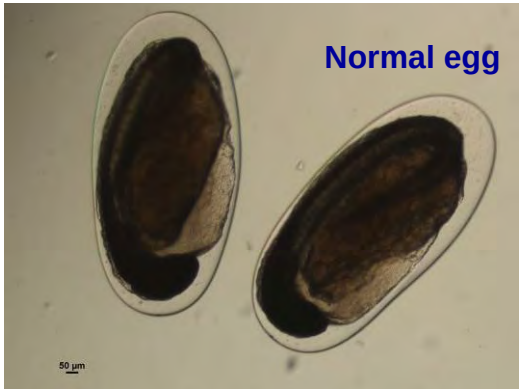
Assessing fishery damages ——How?

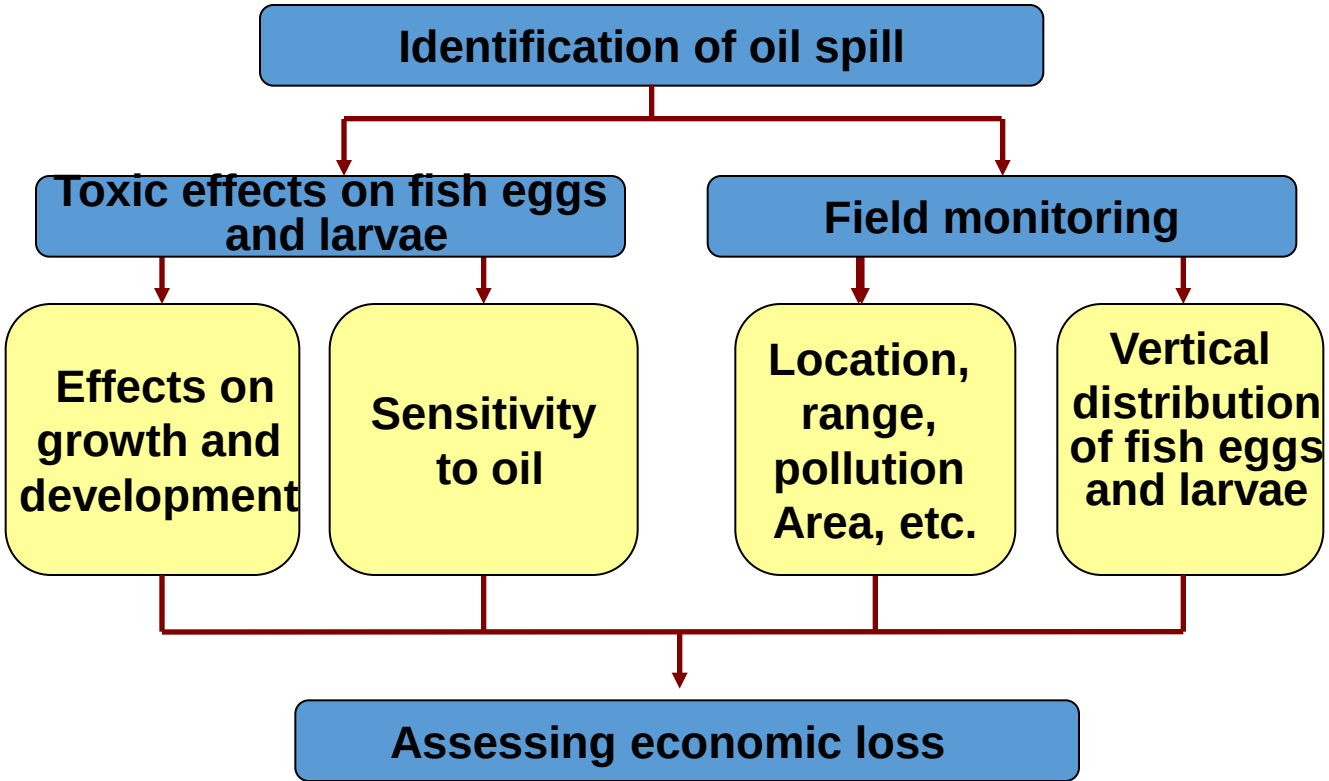
There are mainly 9 calculating methods on the economic loss of fishery caused by the oil spills including "direct calculation method", "comparison method", "fixed sampling station capture method", "expert evaluation method", "fish eggs -larvae evaluation method", "statistical estimation method", "investigation-statistics method", "production method", and "production statistics method". We can choose appropriate method according to polluted waters, polluted marine organism, degree of contamination, historical survey data, monitoring data, and so on.



Quantitative assessment technology of effects on early life stage of fishery resources

Oil spills have damages not only on adult fishery resources, but the larvae. To assess this kind of loss, we choose fish eggs and larvae as a sensitive index for assessment. How to assess the economic loss cause by oil spill is shown in the following figure.





Quantitative assessment technology of effects on early life stage of fishery resources

Loss of fish eggs and larvae was estimated with the equation as follows:

$$Y_z = \sum_{i=1}^{n} D_i \cdot V_p$$

Where

- Y_Z **is loss of fish eggs and larvae**
- D_i **is loss of each fish eggs and larvae**
- V_p **is polluted area or volume**

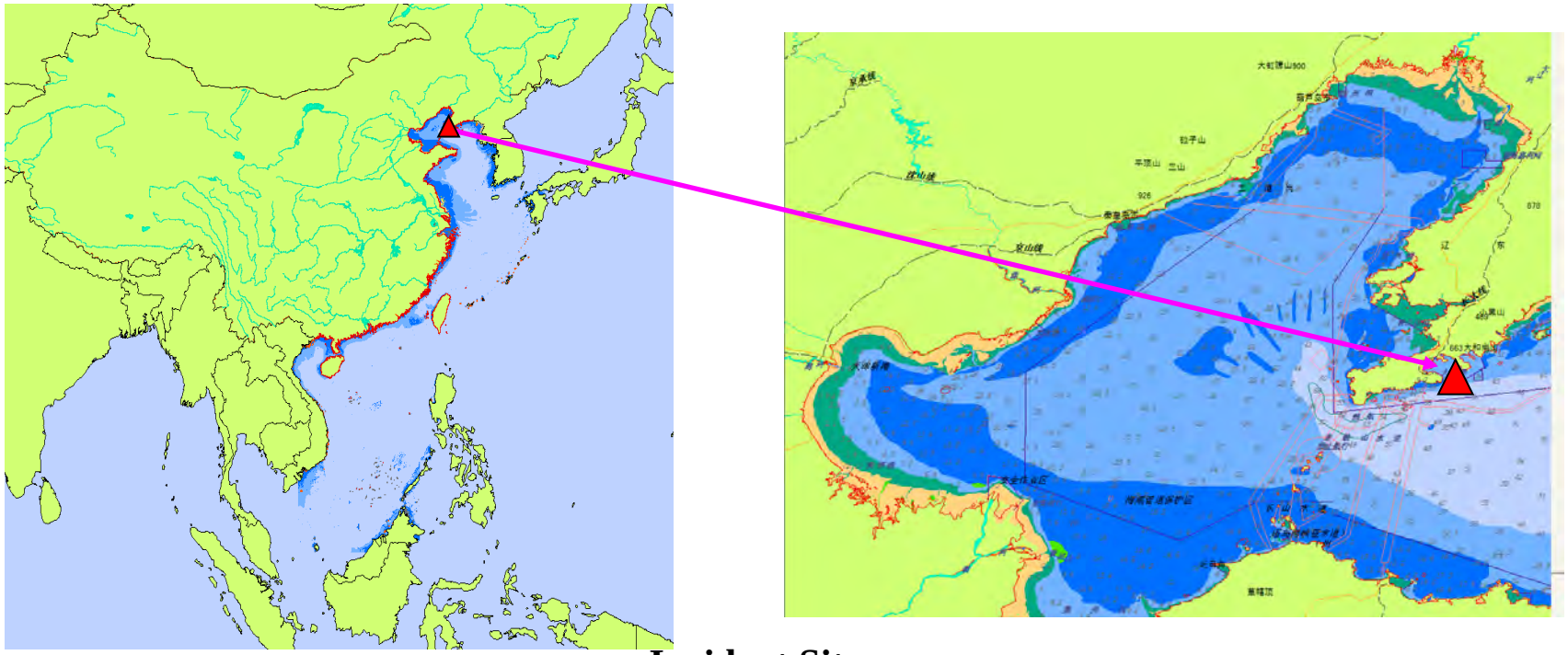
Economic loss was calculated with the following equation:

$$L_z = Y_z \cdot P_d \cdot K_h$$

Where

- L_Z **is economic loss of fish eggs and larvae**
- Y_Z **is loss of fish eggs and larvae**
- P_d **is price of fishery resources**
- K_h **is conversion ratio from fish eggs and larvae to fish eggs and larvae, the fish egg is 1% and the larvae is 5%.**

Assessing fishery damages ——Case studies



Incident Site

On July 16, 2010, an oil pipeline near Xingang in Dalian explored, resulting in 850km^2 waters contaminated by oil. This time was an important period for fish spawning, so the damages of fish eggs and larvae should be carefully considered.

Assessing fishery damages ——Case studies

Calculating method & results

Fish egg loss=Density of fish eggs × polluted volume

$=1.03 ind./ m^3 \times 850 \times 10^6 m^2 \times 0.8m = 69598 \times 10^6$（ind.）

Economic loss=Fish egg loss × Conversion ration × Average price

=695980000 ind.×1%×1.0yuan/ind.

=6959800yuan=6.96（million yuan）

Larvae loss=Density of larvae × polluted volume

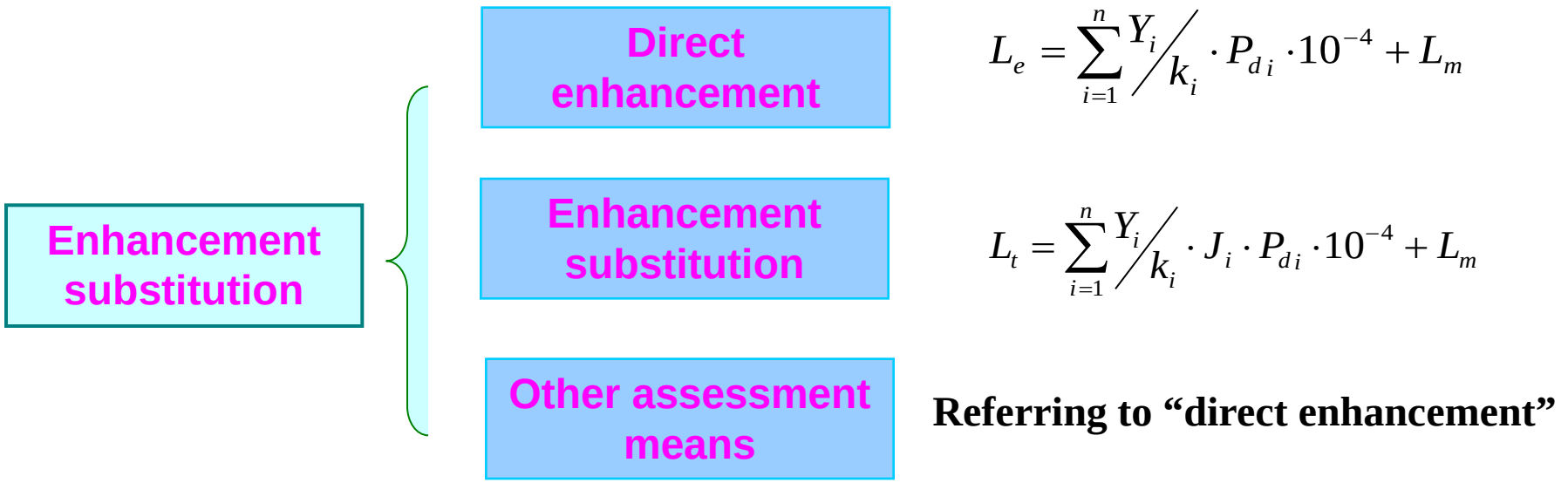
$=0.23 ind./m^3 \times 850 \times 10^6 m^2 \times 0.8m = 15300 \times 10^6$（ind.）

Economic loss=Larvae loss×Conversion ration×average price

$=15300 \times 10^6$ ind.×5%×1.0yuan/ind.=7650000元=7.65 （million yuan）

Middle and long term loss assessment

Besides the direct economic loss of natural fish resources, oil spills also cause middle and long term damages, so we propose the method "enhancement substitution" to assess this part of losses. In this method, we assume that the middle and long term economic loss is equal to the cost of enhancement and releasing of fish resources. the "enhancement substitution" including 3 means: direct enhancement and releasing, enhancement substitution and the others (as follows).



Assessing fishery damages ——Case studies

In May of 2007, Chinese wheel "Jinsheng" (4822 tons) collided with South Korean cargo ship "Golden Rose"(3800 tons) and "Golden Rose" ship sank. About 285.4 km^2 of the seawaters was polluted in Bohai Strait. Besides the direct economic losses of 1.11 million yuan for natural fishery resources, we first used "enhancement substitution" to assess the middle and long term losses.

Middle and long term loss in "Golden Rose" Oil Spill Accident

Direct enhancement： ***Hexagrammos otakii*, *Sebastes schlegeli*, *Portunus trituberculatus***

Enhancement substitution: For some high value species that could not be directly enhance.

Other assessment means： For some low value species, the economic loss is greater or equal to 3 times of direct economic losses.

Assessing fishery damages ——Case studies

There are still no mature artificial breeding technologies for some high value species, so it is not feasible to use these species for enhancement. Meanwhile, these species were important in the polluted sea area, so we chose some substitution species to assess the loss according to their classification and prices. The following table shows some substitution species in "Golden Rose" Oil Spill Accident.

Polluted species	Substitution species	Substitution Coefficient	Prices
Pampus argenteus	*Pagrosomus major*	1.7	*Pampus argenteus* 50yuan/kg, *Pagrosomus major* 30yuan/kg
Scomberomorus niphonius	*Lateolabrax japonicus*	0.8	*Scomberomorus niphonius* 16yuan/kg, *Lateolabrax japonicus* 20yuan/kg
Perch	*Lateolabrax japonicus*	0.7	Perch 14yuan/kg, *Lateolabrax japonicus* 20yuan/kg
Pseudosciaena polyactis Bleeker	*Lateolabrax japonicus*	0.4	*Pseudosciaena polyactis Bleeker* 8yuan/kg, *Lateolabrax japonicus* 20yuan/kg
Flatfish	*Paralichthysolivaceus*	0.5	Flatfish 15yuan/kg, *Paralichthysolivaceus* 30yuan/kg
Charybdis japonica	*Portuns trituberculatus*	0.71	*Charybdis japonica* 25yuan/kg, *Portuns trituberculatus* 35yuan/kg
Oratosquilla oratoria	Shrimp	0.67	*Oratosquilla oratoria* 20yuan/kg, Shrimp30yuan/kg
Trachypenaeus curvirostris	Shrimp	0.33	*Trachypenaeus curvirostris* 10yuan/kg, Shrimp 30yuan/kg

Assessing fishery damages ——Case studies

In "Golden Rose" Oil Spill Accident, the total fishery resources recovery cost is about 5.89 million yuan, including the direct fishery resources recovery cost and substitution species recovery cost .

Species	Fishery Loss(kg)	Average weight (g/ind.)	Quantity(ind.)	Larvae survival rate(%)	Compensation species (ind.)	Price (yuan/ind.)	compensations (ten thousand)
Direct fishery resources recovery cost							
Sebastods schlegeli	1271	57.8	21976	10	219760	1.0	22.0
Hexagrammos otakii	874	45.7	19122	10	191220	2.0	38.2
Portunus trituberculatus	1506	53.3	28255	5	282550	0.1	5.6
Flatfish	2377	95.7	24830	10	248300	1.5	18.6
Substitution species recovery cost							
Pampus argenteus	3699	62.0	59649	10	596490	1.7	152.1
Scomberomorus niphonius	12111	186.9	64786	10	647860	1.5	77.7
Perch	1329	137.0	9703	10	97030	1.5	10.2
Pseudosciaena polyactis Bleeker	9584	35.9	267134	10	2671340	1.5	160.3
Charybdis japonica	1500	37.5	39956	5	399560	0.1	5.6
Trachypenaeus curvirostris	1838	4.8	382721	1	38272100	0.016	20.2
Oratosquilla oratoria	14119	19.4	727770	1	72777000	0.016	78.0
Total							588.5

Assessing fishery damages ——Applicaitons

Pesticide Pollution

Waste Water Pollution

Reclamation Pollution

Thermal Discharge Pollution

Thanks !