Acoustic Evaluation of Fishery Resources in Seawater Reservoir and Water-Intake Open Channel of Taishan Nuclear Power Plant

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Abstract. The CGN Taishan NPP seawater storage is a land-sealed type and is connected to the open water intake channel of Dajin Island in the open sea through a subsea tunnel. Due to the impact of large-scale facility aquaculture in the nearby seas, fish spawning grounds have been formed in this area, and fish breeds faster. A large number of fish have impacted on safe operation of nuclear power. In response to this situation, this study conducted acoustic navigation surveys of fish resources in most waters of the “Sea Reservoir” and “Water intake channel”, using broadband scientific fish finder system (EK80, 120kHz, 200kHz) produced by Norwegian Simrad Company. Evaluation of acoustic resources using echo integration method. The survey scope of seawater storage in this survey is from the entrance to the first barrier (around a distance of 760m) and from the first barrier to a second barrier (around a distance of 220m); the survey distance of the water intake channel is about 1460m. From the echo image, it can be found that the zooplankton in the sea reservoir is much smaller than the water intake channel, and the fish size of the water intake channel is much larger than that of the sea channel.Acoustic data was processed and analyzed using Echoview software to calculate the average SV and detect the strength of the single target. The results show that in the survey area of the Taishan Nuclear Power Plant Hai Reservoir, the total number of fish is about 1.38 million, the total weight is about 13.6 tons, and the fish with a body length of less than 20cm is the majority, and there are fewer large-sized fish; The total resources in the survey area is about 47 tons, with a total number of 27 million, and has a high density.

1 Introduction

The reservoir of CGNPC Taishan Nuclear Power Plant is a land closed-type reservoir connected to water-intake open channel on Dajin Island in open seas via subsea tunnel (Fig.1). Impacted by large-scale breeding industry in surrounding waters, a good fish spawning ground is formed in this area with fast fish reproduction. Both the seawater reservoir and water-intake open channel have been found with many fish species, which exert an influence on safe nuclear power operation [1].

Acoustic investigation and evaluation method of fishery resources has been more and more extensively applied to fields like fishery resource evaluation and eco-environmental investigation by virtue of high efficiency and convenient comparative analysis not needing any contact, and moreover, it does not damage fishery resources and echo image data can be saved and played back[2], and it has become an important ecological monitoring means both home and abroad[3-6]. Relevant domestic researches started in 1913. With increasing fundamental acoustic researches on the fishery industry and promotion of practical application technologies in recent years, this method has been widely applied to fishery resource investigation and evaluation of the Yellow Sea, the East Sea and the South China Sea as well as main inland rivers like the Yangtze River and the Pearl River,and also lakes and reservoirs, and outstanding effects have been achieved[7-13]. Therefore, a fishery resource investigation was carried out this time for most water areas (areas marked with design courses) in “seawater reservoir” and “water-intake open channel” (note: water area before coarse screen of seawater reservoir is a safety restricted area, and the first half part of water-intake open channel is a sea area in construction). As the nuclear power plant was in shortage of necessary sampling netting gears, acoustic vessel-mounted method was adopted in this investigation and resource evaluation was implemented using echo integral method[14].

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Fig.1 Acoustic design drawing of seawater storage (top) and water intake channel (bottom) at Taishan nuclear power plant

2 Investigation materials and methods

Broadband scientific fish finder system produced by Norwegian Simrad Corporation (EK80, 120 kHz, 200 kHz) was used in this investigation to collect fish echo data, and position data were received by GPA, which was produced by Garmin, synchronously with the scientific fish finder system through RS232 serial port. Vessel-mounted sampling method was adopted to collect acoustic data, and the course was designed as a triangle as seen in Fig.1 (course-free area was unsampled area in this investigation),where the cross-course design interval for sampling in the seawater reservoir was 35 m and that in the water-intake open channel was 100 m (Fig.1). The investigation date of the seawater reservoir was June 18, 2019 and that of the water-intake open channel was June 19.

DC12V storage battery was used to supply power which was transformed into AC220V output via inverter and then supplied to the scientific fish finder, network switch and data acquisition PC.The purpose-made special stand was used to fix the transducer at ship' s rail with draught of 50 cm. The investigation ship was a small sunshade-free boat with fiberglass reinforced plastic structure and tail diesel engine, it was about 6 m in length, and the diesel engine was of 6 horsepower. Fig. 2 displays field working pictures. Data processing was implemented using Australian Echoview software.

Fig.2 Acoustic survey of seawater storage in Taishan nuclear power plant

3 Investigation results

3.1. Investigation map

Actual investigation track lines and statistical areas of the seawater reservoir and water-intake open channel are shown in Fig.3 and Fig.4. The purple part is 2m water depth part at the edge of the seawater reservoir and the green part is current bubble area at its entrance. The distance from entrance of the seawater reservoir to the first intercepting net was about 760m and that from the first intercepting net to the second one was 220m or so. The investigation distance of the water-intake open channel was about 1,460m. The statistical areas extended from the south to north, the seawater reservoir was divided into 4 areas (Fig.3), where intercepting nets existed between area 4 and areas 1-3. The water-intake open channel was divided into 3 areas from the south to north (Fig.4).

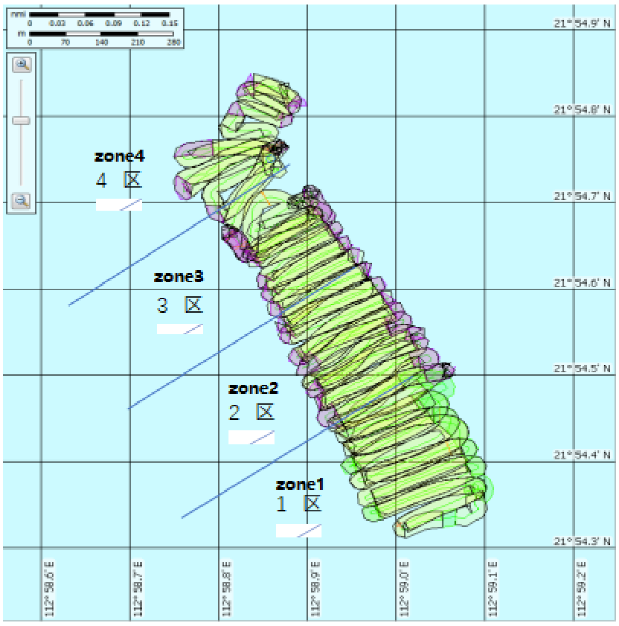

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Fig.3 Acoustic survey track and statistical partition of fish stocks in seawater storage at Taishan nuclear power plant

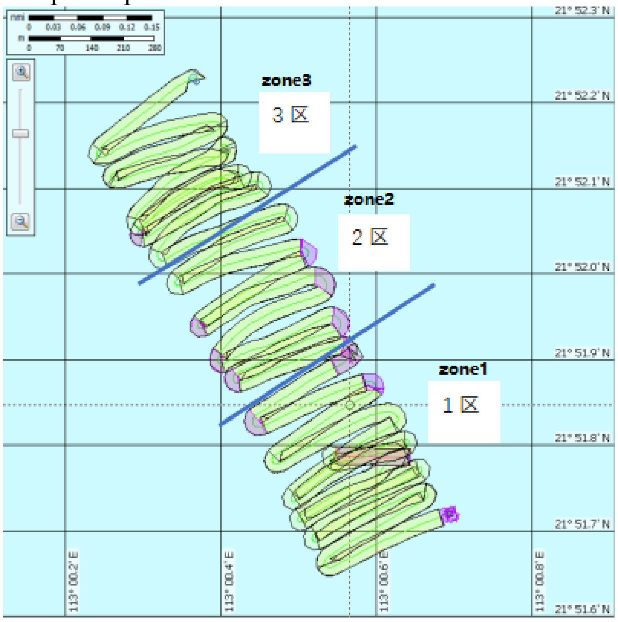

Fig.4 Acoustic survey track of fish stocks in water intake channel at Taishan nuclear power plant

3.2. Fish echo images

The echo images of investigation courses in the seawater reservoir and water-intake open channel are shown in Fig.5, where red band represents seabed echo, red plaque-shaped echo is small-sized fish school echo, and what is dispersive is target echo of monomer fish. Individual target echo intensity is in direct proportion to fish body length, so is echo intensity of fish school to school density. By comparing the echoes of the seawater reservoir and water-intake open channel, zooplanktons in the seawater reservoir were much smaller than those in the water-intake open channel, and fish specifications in the water-intake open channel are much larger than those in the seawater reservoir.

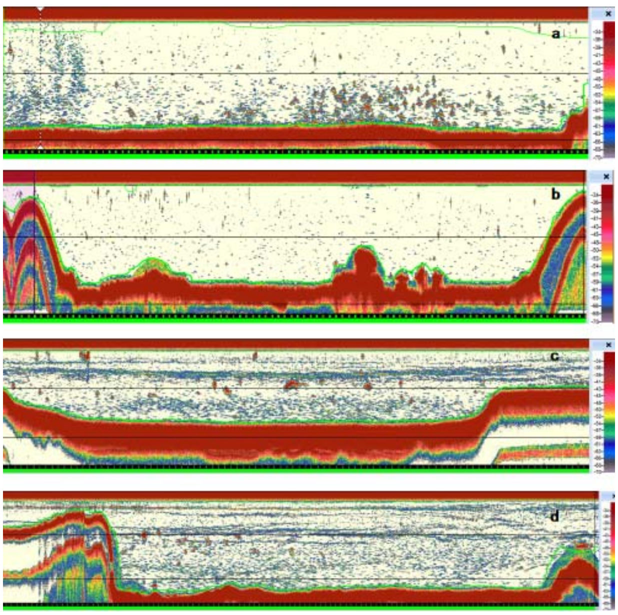

Fig.5 The features of fish echo distribution in different areas:

(a) dense fish school near the seabed in seawater storage area 1;

(b) small size single fish in seawater storage area 4, water depth about 8m;

(c) fish school (red) in water intake channel 1, water depth about 8m;

(d) single target in 5-6m water layer on the last course in water intake channel 3, water depth is about 12 meters, span is about 300m

3.2. Backward acoustic volume scattering intensity of fish (SV) in different areas of the investigated waters

The acoustic echo data of each course were processed, and the echoes of sea surface, seabed and other non-water bodies were excluded to calculate average backward target volume scattering intensity (SV) of each course, and the results are shown in Fig.6, where the starting point is water inlet of the seawater reservoir and the end point is intercepting net in the waters outside coarse screen of the power plant, and different distance intervals (areas1-4) between the two places are corresponding to average acoustic reflection coefficient (SV) of fish schools investigated in each course, and this value represents the overall quantity of fish resources. SV value in area 3 is the maximum while that in area 4 is the minimum. Fig.7 shows average SVs in different areas of the water-intake open channel, where average SV in area 1 is the highest and those in areas 2 and 3 are relatively low.

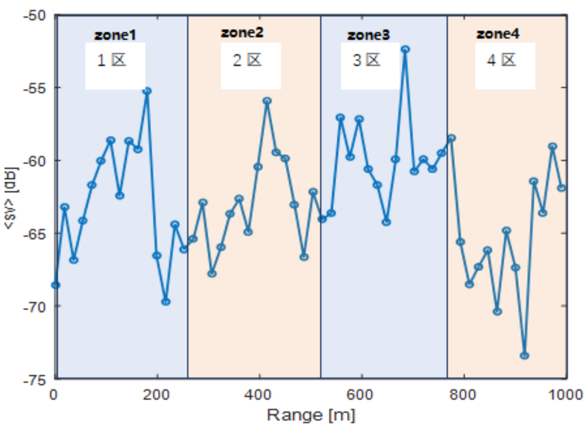

Fig.6 Average Sv of fish in different regions in seawater storage

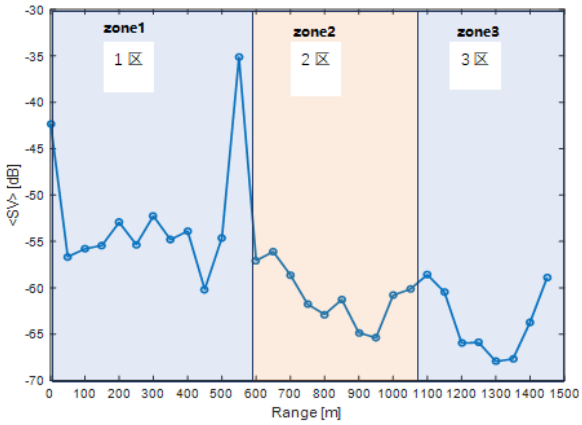

Fig.7 Average Sv of fish in different regions in water intake channel

3.4. Aqueous layer distribution of fish species of different specifications in different areas of the seawater reservoir

Aqueous layer (depth) distribution of individual target fish with body length exceeding 5 cm in the seawater reservoir was carried out. The conversion formula between fish target strength (TS) and fish body length refers to formula 1 in section 3.5. The results of areas 1-4 are displayed in Fig.8-11, where y-coordinate is water depth, and x-coordinate denotes fish target strength (convertible with body length).

Fish targets with body length ranging from 5 cm (TS: -50 dB) to 17 cm (TS: -41 dB) in area 1 were mainly distributed within the interval of 6 m-9 m; that in area 2 was 5 m-9 m; that in area 3 was 6 m-9 m; that in area 4 was 7 m-9 m, where the number of aqueous layers where the fish targets were located was small. The aqueous layer distribution of large-size fish in area 1 was relatively uniform; They were distributed at two aqueous layers in area 2, namely 5m and 8m aqueous layers; They were mostly distributed at 6m depth in area 3; They were distributed only at about 8m depth in area 4.

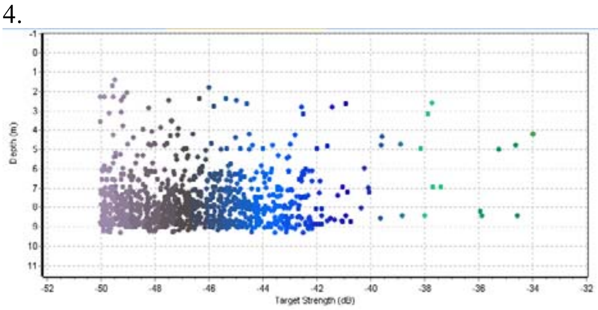

Fig.8 Vertical distribution of fish of different sizes in seawater storage 1

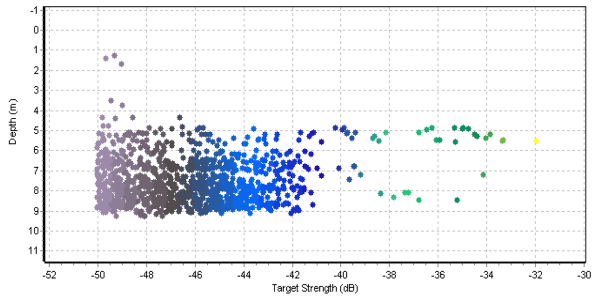

Fig.9 Vertical distribution of fish of different sizes in seawater storage 2

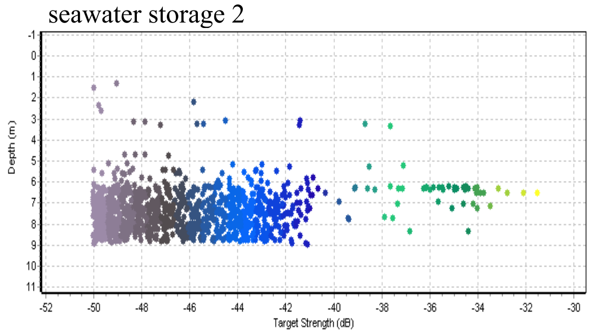

Fig.10 Vertical distribution of fish of different sizes in seawater storage 3

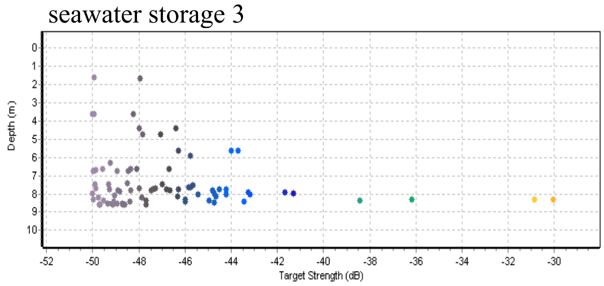

Fig.11 Vertical distribution of fish of different sizes in seawater storage 4

3.5. Density and quantity of fish resources

According to the distribution of individual target strength (TS), average body length Lcm of fish within different specification intervals is derived;

$$TS=20\log L_{cm}-66 \quad (1)$$

The average density of fish within different specification intervals is calculated via echo integral method; The body length/body weight conversion relational model of millet is used as below,

$$W_g=1{,}2716\times10^{-5}L_{cm}^{3.0695} \quad (2)$$

Where unit of body weight wg is g and that of body length Lcm is cm. The average weight corresponding to average body length within different specification intervals is deduced, and total weight (resource quantity) is the product of average density with the area and average weight.

The investigation results are presented as follows:

(1) Investigation results of the seawater reservoir

In the investigated area of the seawater reservoir in Taishan Nuclear Power Plant, the density and weight of fish of different specifications in different intervals are seen in Tab.1, where total quantity is about 1,380,000 and total weight is about 13.6 t. The investigation results of the seawater reservoir are: fish with body length being smaller than 20 cm account for the vast majority, and there are few fish of large specifications, and the quantity of fish with body length exceeding 40 cm is about 1,400.

Tab.1 Fish resources in different regions in seawater storage at Taishan nuclear power plant

Partition	Body length specifications/cm	<10	10<L<20	20<L<30	30<L<40	>40	Total
1 Area	Weight/t	0.68	1.09	0.18	0.24	0.28	2.48
	Quantity/tail	378493	31092	856	389	156	410984
2 Area	Weight/t	0.54	1.06	0.24	0.61	0.44	2.88
	Quantity/tail	316723	29435	1167	1037	259	348623
3 Area	Weight/t	0.81	1.77	0.39	1.75	1.27	5.99
	Quantity/tail	455469	45393	1849	2876	719	506305
4 Area	Weight/t	0.15	0.12	0.04	0.11	1.87	2.29
	Quantity/tail	111600	4038	184	184	367	116372

(2) Investigation results of the water-intake open channel

The resource quantity in the water-intake open channel is seen in Tab.2. The total resource quantity in this investigated area is about 47 t and total quantity is 27 million.

Tab.2 Fish resources in different regions in water intake channel at Taishan nuclear power plant

Partition	Body length specifications/cm	<10	10<L<20	20<L<30	30<L<40	>40	Total
1 Area	Weight/t	8.12	10.32	10.62	4.94	0.00	34.00
	Quantity/tail	16042608	251223	50245	8104	0	16352179
2 Area	Weight/t	1.84	1.59	0.98	1.41	0.00	5.83
	Quantity/tail	6129960	39433	4639	2320	0	6176353
3 Area	Weight/t	1.78	1.03	0.29	1.68	2.42	7.19
	Quantity/tail	5140621	32970	1374	2748	1374	5179087

4 Result analysis

As the investigation boat used this time was made of fiberglass and tail-hanging diesel engine was used to supply power, large vibration noise would be generated, and at the bottom of the seawater reservoir were hard stones, intimidating effect was then formed on large-size fish, fish would then escape, and the quantity of probed large-size fish would be partially small. Hence, electric impetus generating small noise is recommended.

As the boat was forbidden to get close to the gate of the seawater reservoir, acoustic sampling was insufficient in this area, and then the calculated resource quantity was also partially small. The flow velocity was high nearby the gate entrance in the seawater reservoir with many bubbles, which formed a great impact on acoustic sounding. A measurement dead zone was formed in this area, which could influence the evaluation accuracy to a certain degree.

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