Isothermal Water Mass in the Bottom Water at the Bay Mouth of Jiaozhou Bay II. Isothermal Water Mass scale and location

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Abstract: Based on the survey data on Jiaozhou Bay in May, June, July, August, September and October 1980, the bottom water temperature and its horizontal distribution in Jiaozhou Bay were studied. The results showed that the author put forward the definition of isothermal water mass and determined the scale and location of the isothermal water mass. According to Yang Dongfang’s definition of “Isothermal Water Mass”, it was revealed that the temperature of isothermal water mass in the inner part of the bay mouth was higher than that in the outer part of the Bay mouth in May, June, July and August. In September and October, the temperature of isothermal water mass in the inner part of the bay mouth was lower than that in the outer part of the Bay mouth. Moreover, the number, location, scale and temperature variation sequence of isothermal water masses were determined by the sea water temperature and its variation trend in both June and October.

1. Introduction
Oceans play an important role in climate change [1]. On the basis of investigation data in 1980, the author put forward the definition of isothermal water mass, and studied the scale and location of the isothermal water mass, providing a scientific background for a comprehensive analysis of the isothermal zone in the bottom water of Jiaozhou Bay and a theoretical basis for the change of the bottom water temperature.

2. Materials and Methods Used in the Investigation of the Waters

2.1 Natural Environment of Jiaozhou Bay
Located in the Shandong Peninsula south, between 120°04′~120°23′ E and 35°58′~36°18′N, Jiaozhou Bay is a typical semi-enclosed bay with an area of 446 km² and an average water depth of 7m. It is adjacent with the Yellow Sea. There are more than a dozen seagoing rivers in Jiaozhou Bay, including Dagu River, Haibo River, Licun River and Loushan River with hydrological characteristics in seasonal changes [2].

2.2 Materials and Methods
The data on water temperature of Jiaozhou Bay in May, June, July, August, September and October
Water samples were taken from eight stations set in Jiaozhou Bay in May, June, July, August, September and October respectively and were marked as H34, H35, H36, H37 and H82 (Fig. 1). When the water depth is more than 10m, it is supposed to take samples from surface layer and bottom layer; when less than 10m, to take from the surface layer only, by the national standard method of sampling in “The Specification for Marine Monitoring” (1991)).

3. Results and Discussions

3.1 Definition of Isothermal Water Mass

Yang Dongfang put forward the concept of “Water Mass”. It refers to a waterbody which consists of one point, two points or more points sharing common characteristics. Hence, it is called a water mass with certain characteristics. In order to distinguish this concept from others alike, some authors proposed to define it as “Yang Dongfang Water Mass”. Moreover, Yang Dongfang further put forward the concept of “Isothermal Water Mass”, defined as the waterbody of an area sharing the similar temperature with the surrounding areas. It is also called “Yang Dongfang’s Isothermal Water Mass”, referred to as the “Isothermal Water Mass” for short.

3.2 Location of Isothermal Water Masses at the Bottom Layer

In May, the bottom water temperature of Jiaozhou Bay ranged between 10.18°C-12.35°C. In Jiaozhou Bay, the seawater temperature was very low. According to Yang Dongfang's definition of “Isothermal Water Mass”, there were three isothermal water masses in the waterbody of Jiaozhou Bay (Fig. 2), and they were in the waters inside the bay mouth, the waters at the bay mouth and the waters outside the bay mouth. The interval lengths of the seawater temperature variation in the three isothermal water masses were 0.10°C, 0.00°C and 0.06°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.10°C.

In June, the bottom water temperature of Jiaozhou Bay ranged between 15.09°C-18.77°C. In Jiaozhou Bay, the seawater temperature was relatively low. According to Yang Dongfang's definition of “Isothermal Water Mass”, there were three isothermal water masses in the waterbody of Jiaozhou Bay (Fig. 3), and they were in the waters at the bay mouth and in the western waters inside the bay mouth, the eastern waters inside the bay mouth, and the waters outside the bay mouth. The interval lengths of the seawater temperature variation in the three isothermal water masses were 0.06°C, 0.00°C and 0.23°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.23°C.
In July, the bottom water temperature of Jiaozhou Bay ranged between 18.67°C-20.49°C. In Jiaozhou Bay, the seawater temperature was relatively high. According to Yang Dongfang's definition of “Isothermal Water Mass”, there were three isothermal water masses in the waterbody of Jiaozhou Bay (Fig. 4), and they were in the waters inside the bay mouth, the waters at the bay mouth and in the northern part outside the bay mouth, and the southern waters outside the bay mouth. The interval lengths of the seawater temperature variation in the three isothermal water masses were 0.29°C, 0.00°C and 0.23°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.29°C.

In August, the bottom water temperature of Jiaozhou Bay ranged between 24.58°C-25.72°C. In Jiaozhou Bay, the seawater temperature was extremely high. According to Yang Dongfang's definition of “Isothermal Water Mass”, there were two isothermal water masses in the waterbody of Jiaozhou Bay (Fig. 5), and they were in the waters inside the bay mouth and at the bay mouth, and the waters outside the bay mouth. The interval lengths of the seawater temperature variation in the two isothermal water masses were 0.52°C and 0.22°C respectively, which indicated that the general interval length of water temperature variation was 0.22°C-0.52°C.
Fig. 5 Temperature in the bottom water of Jiaozhou Bay in August 1980 (℃)

In September, the bottom water temperature of Jiaozhou Bay ranged between 23.79 ℃-24.43 ℃. In Jiaozhou Bay, the seawater temperature was extremely high. According to Yang Dongfang's definition of “Isothermal Water Mass”, there were two isothermal water masses in the waterbody of Jiaozhou Bay (Fig. 6), and they were in the water inside the bay mouth-at the bay mouth-in the southern waters outside the bay mouth and the northern water outside the bay mouth. The interval lengths of the seawater temperature variation in the two isothermal water masses were 0.12 ℃ and 0.00 ℃ respectively, which indicated that the general interval length of water temperature variation was 0.00 ℃-0.12 ℃.

Fig. 6 Temperature in the bottom water in September 1980 (℃)

Fig. 7 Temperature in the bottom water in October 1980 (℃)

In October, the bottom water temperature of Jiaozhou Bay ranged between 15.53 ℃-20.04 ℃. In Jiaozhou Bay, the seawater temperature was relatively low. According to Yang Dongfang's definition of “Isothermal Water Mass”, there were three isothermal water masses in the waterbody of Jiaozhou Bay (Fig. 7), and they were in the waters at the bay mouth and in the western waters inside the bay mouth, the eastern waters inside the bay mouth, and the waters outside the bay mouth. The interval lengths of the seawater temperature variation in the three isothermal water masses were 0.31 ℃, 0.00 ℃ and 0.04 ℃ respectively, which indicated that the general interval length of water temperature variation was 0.00 ℃-0.31 ℃.

Tab. 1 The interval length of the temperature variation in the bottom layer of the waterbody of Jiaozhou bay in May, June, July, August, September and October

| Month    | May | June | July | August | September | October |
|----------|-----|------|------|--------|-----------|---------|
| Interval |     |      |      |        |           |         |
Therefore, the core index of the Yang Dongfang’s Isothermal Water Mass is the interval length of water temperature variation (Tab.1). The interval length of the temperature variation of Yang Dongfang’s Isothermal Water Mass in Jiaozhou Bay was 0.00°C-0.52°C.

### 3.3 Scale of Isothermal Water Mass in the Bottom Layer

In May, there were three isothermal water masses in the waters inside the bay mouth, the waters at the bay mouth, and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 2). The seawater temperature in May was extremely low. Two water temperature interfaces formed in the waters inside the bay mouth and the waters at the bay mouth and outside the bay mouth, which indicated that the feature of the bay mouth determined the water temperature variation inside and outside the bay mouth.

In June, there were three isothermal water masses in the waters at the bay mouth and in the western waters inside the bay mouth, the eastern water inside the bay mouth, and the water outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 3). The seawater temperature in June was relatively low while higher than of May. Thus, two water mass formed in the western waters inside the bay mouth and the eastern waters inside the bay mouth respectively. The water mass in the western waters inside the bay mouth and the water mass at the bay mouth mixed together, which formed a new structure. The water mass outside the bay mouth did not change.

In July, there were three isothermal water masses in the waters inside the bay mouth, the waters at the bay mouth and in the northern waters outside the bay mouth, and the southern waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 3). The seawater temperature in July was relatively high and showed further increase. Thus, two water mass formed in the southern waters outside the bay mouth and the northern waters outside the bay mouth respectively. The water mass in the northern waters outside the bay mouth and the water mass at the bay mouth mixed together, which formed a new structure. Another water mass formed inside the bay mouth.

In August, there were two isothermal water masses in the water inside the bay mouth and at the bay mouth, and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 5). The seawater temperature in August was extremely high and reached to the peak value. Thus, the water mass inside the bay mouth and the water mass at the bay mouth mixed together, which formed a new water mass. Another water mass formed outside the bay mouth.

In September, there were two isothermal water masses in the waters inside the bay mouth-at the bay mouth-in the southern part outside the bay mouth, and the northern waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 6). The seawater temperature in September was relatively high and showed decline. Expanding further at the bottom layer, the water mass inside the bay mouth and the water mass at the bay mouth mixed together, and then mixed the water mass in the southern water outside the bay mouth, which formed a new water mass. Another water mass formed in the northern waters inside the bay mouth.

In October, there were three isothermal water masses in the water at the bay mouth and in the western waters inside the bay mouth, the eastern water inside the bay mouth, and the water outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 7). The seawater temperature in October was relatively low and showed further decline. As a result, the bottom water mass inside the bay mouth shrunk and evolved into the western water mass inside the bay mouth and the eastern water mass inside the bay mouth. The western water inside the bay mouth and the water mass at the bay mouth mixed together, which formed a new structure. The water mass outside the bay mouth
recovered and developed into another one.

3.4 Temperature of Isothermal Water Mass at the Bottom Layer
In May, there were three isothermal water masses in the water inside the bay mouth, the water at the bay mouth and the water outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 2). The temperature of the three water masses respectively ranged between 12.25°C-12.35°C, 11.63°C-11.63°C and 10.18°C-10.26°C, which indicated that the isothermal water mass in the waters inside the bay mouth was hotter than that in the waters at the bay mouth and the latter was hotter than that in the waters outside the bay mouth in May.

In June, there were three isothermal water masses in the waters at the bay mouth and in the western waters inside the bay mouth, the eastern waters inside the bay mouth, and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 3). The temperature of the three water masses respectively ranged between 17.38°C-17.44°C, 18.77°C-18.77°C and 15.09°C-15.32°C, which indicated that the isothermal water mass in the eastern water inside the bay mouth was hotter than the isothermal water mass in the water at the bay mouth and in the western part inside the bay mouth and the latter was hotter than the isothermal water mass in the water outside the bay mouth in June.

In July, there were three isothermal water masses in the waters inside the bay mouth, the waters at the bay mouth and in the northern waters outside the bay mouth, and the southern waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 4). The temperature of the three water masses respectively ranged between 20.20°C-20.49°C, 19.68°C-19.78°C and 18.67°C-18.67°C, which indicated that the isothermal water mass in the waters inside the bay mouth was hotter than the isothermal water mass in the waters at the bay mouth and in the northern waters outside the bay mouth and the latter was hotter than the isothermal water mass in the southern waters outside the bay mouth in July.

In August, there were two isothermal water masses in the waters inside the bay mouth and at the bay mouth, and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 5). The temperature of the two water mass respectively ranged between 25.20°C-25.72°C and 24.58°C-24.80°C, which indicated that the isothermal water mass in the waters inside the bay mouth and at the bay mouth was hotter than the isothermal water mass in the waters outside the bay mouth in August.

In September, there were two isothermal water masses in the waters inside the bay mouth-at the bay mouth-in the southern waters outside the bay mouth, and the northern waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 6). The temperature of the two water mass respectively ranged between 23.79°C-23.91°C and 24.43°C-24.43°C, which indicated that the isothermal water mass in the waters inside the bay mouth-at the bay mouth-in the southern part outside the bay mouth was colder than the isothermal water mass in the northern waters outside the bay mouth in September.

In October, there were three isothermal water masses in the waters at the bay mouth and in the western waters inside the bay mouth, the eastern waters inside the bay mouth, and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 7). The temperature of the three water mass respectively ranged between 16.33°C-16.74°C, 15.53°C-15.53°C and 20.00°C-20.04°C, which indicated that the isothermal water mass in the eastern waters inside the bay mouth was colder than the isothermal water mass in the waters at the bay mouth and in the western waters inside the bay mouth and the latter was colder than the isothermal water mass in the waters outside the bay mouth in October.

3.5 Variation of Bottom Isothermal Water Mass in Terms of Time
In May, June, July and August, the temperature in the waterbody of Jiaozhou Bay was rising, which indicated that the isothermal water mass inside the bay mouth was hotter than the isothermal water mass at the bay mouth and the latter was hotter than the isothermal water mass outside the bay mouth
In September and October, the temperature in the waterbody of Jiaozhou Bay was declining, which indicated that the isothermal water mass inside the bay mouth was colder than the isothermal water mass at the bay mouth and the latter was colder than the isothermal water mass outside the bay mouth during this period.

In June, the bottom water temperature of Jiaozhou Bay ranged between 15.09°C-18.77°C. The seawater temperature in Jiaozhou Bay was relatively low. In October, the bottom water temperature of Jiaozhou Bay ranged between 15.53°C-20.04°C. The seawater temperature in Jiaozhou Bay was relatively low from June to October, and the water temperature variation range within each month was basically same. In June, there were three isothermal water masses in the waters at the bay mouth and in the western waters inside the bay mouth, the eastern waters inside the bay mouth and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 3). The interval lengths of the seawater temperature variation in the three isothermal water masses were 0.06°C, 0.00°C and 0.23°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.23°C. In October, there were three isothermal water masses in the water at the bay mouth and in the western waters inside the bay mouth, the eastern waters inside the bay mouth and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay (Fig. 7). The interval lengths of the seawater temperature variation in the three isothermal water masses were 0.31°C, 0.00°C and 0.04°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.31°C. Thus, it can be concluded that there were three isothermal water masses in the waters at the bay mouth and in the western waters inside the bay mouth, the eastern waters inside the bay mouth and the waters outside the bay mouth respectively in the bottom layer of Jiaozhou Bay both in June and October, and the interval length of seawater temperature variation of the three isothermal water mass within each month was basically same. In June, the temperature in the waterbody of Jiaozhou Bay was increasing, which indicated that the isothermal water mass in the eastern water inside the bay mouth was hotter than the isothermal water mass in the water at the bay mouth and the latter was hotter than the isothermal water mass in the waters outside the bay mouth in June. In October, the temperature in the waterbody of Jiaozhou Bay was declining, which indicated that the isothermal waters mass in the eastern water inside the bay mouth was colder than the isothermal water mass in the waters at the bay mouth and the latter was colder than the isothermal water mass in the waters outside the bay mouth in October. Thus, it can be concluded that the number, location, scale and temperature variation sequence of isothermal water mass were determined by seawater temperature and its variation trend in both June and October.

4. Conclusion
According to Yang Dongfang's definition of “Isothermal Water Mass”, there were three isothermal water masses in the waterbody of Jiaozhou Bay, and they were in the waters inside the bay mouth, the waters at the bay mouth and the waters outside the bay mouth. The interval lengths of the seawater temperature variation in the three isothermal water masses were 0.10°C, 0.00°C and 0.06°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.10°C. The temperature of the three water mass respectively ranged between 12.25°C-12.35°C, 11.63°C-11.63°C and 10.18°C-10.26°C, which indicated that the isothermal water mass in the water inside the bay mouth was hotter than the isothermal water mass in the water at the bay mouth and the latter was hotter than the isothermal water mass in the water outside the bay mouth in May.

According to Yang Dongfang’s definition of “Isothermal Water Mass”, there were three isothermal water masses in the waterbody of Jiaozhou Bay, and they were in the water at the bay mouth and in the western part inside the bay mouth, the eastern water inside the bay mouth and the water outside the bay mouth. The interval lengths of the seawater temperature variation in the three isothermal water
masses were 0.06°C, 0.00°C and 0.23°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.23°C. The temperature of the three water masses respectively ranged between 17.38°C-17.44°C, 18.77°C-18.77°C and 15.09°C-15.32°C, which indicated that the isothermal water mass in the eastern water inside the bay mouth was hotter than the isothermal water mass in the water at the bay mouth and in the western part inside the bay mouth and the latter was hotter than the isothermal water mass in the water outside the bay mouth in June.

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According to Yang Dongfang's definition of “Isothermal Water Mass”, there were two isothermal water masses in the waterbody of Jiaozhou Bay, and they were in the waters inside the bay mouth and at the bay mouth and the waters outside the bay mouth. The interval lengths of the seawater temperature variation in the two isothermal water masses were 0.52°C and 0.22°C respectively, which indicated that the general interval length of water temperature variation was 0.22°C-0.52°C. The temperature of the two water masses respectively ranged between 25.20°C-25.72°C and 24.58°C-24.80°C, which indicated that the isothermal water mass in the waters inside the bay mouth and at the bay mouth was hotter than the isothermal water mass in the waters outside the bay mouth in August.

According to Yang Dongfang's definition of “Isothermal Water Mass”, there were two isothermal water masses in the waterbody of Jiaozhou Bay, and they were in the waters inside the bay mouth-at the bay mouth-in the southern part outside the bay mouth and the northern waters outside the bay mouth. The interval lengths of the seawater temperature variation in the two isothermal water masses were 0.12°C and 0.00°C respectively, which indicated that the general interval length of water temperature variation was 0.00°C-0.12°C. The temperature of the two water masses respectively ranged between 23.79°C-23.91°C and 24.43°C-24.43°C, which indicated that the isothermal water mass in the waters inside the bay mouth-at the bay mouth-in the southern part outside the bay mouth was colder than the isothermal water mass in the northern waters outside the bay mouth in September.

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In May, June, July and August, the isothermal water mass inside the bay mouth was hotter than the isothermal water mass at the bay mouth and the latter was hotter than the isothermal water mass outside the bay mouth during this period. In September and October, the isothermal water mass inside the bay mouth was colder than the isothermal water mass at the bay mouth and the latter was colder
than the isothermal water mass outside the bay mouth during this period. And the number, location, scale and temperature variation sequence of isothermal water mass were determined by seawater temperature and its variation trend in both June and October.

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