Analysis of Sea Ice Hazard Factors and Influence on Seaport Operations in the Bohai Sea

Xueqin Liu, Yujin Zhang, Danzhu Yu, Shuai Yuan and Wenqi Shi
National Marine Environmental Monitoring Center, Ministry of Ecology and Environment of the People’s Republic of China, Dalian, China

Zhenhua Chen
City and Regional Planning, Knowlton School of Architecture, The Ohio State University
Columbus, Ohio, United States

Floating ice is one of the potential hazards that threatens the safety of seaport operations in winter. In this study, the monitoring data of the ice conditions around the Port of Yingkou in the ice zone of China were analyzed. The results showed a significant negative correlation between changes in cargo throughput and the magnitude level of sea ice. When the ice thickness is more than 15 cm, it can have serious impacts on port operations unless tugboats and icebreakers are deployed to remove sea ice from the channel.

INTRODUCTION

Ports play an important role in a nation’s economic system. Seaports are important nodes of the transportation network and gateways for domestic and global trade. According to data released by the Ministry of Transport of the People’s Republic of China in 2021 (Ministry of Transport of the PRC, 2021), 7 of China’s top 20 seaports in terms of throughput are located in seasonally frozen seas and need to cope with the impact of sea ice in winter. About one-fifth of China’s continental coastline is in seasonally icy seas. The Bohai Sea in northern China is a seasonal ice-covered sea with the lowest latitude in the northern hemisphere. Sea ice hazards are considered to be among the most serious natural disasters in northern China (Eicken and Mahoney, 2015; Liu et al., 2016; Xu et al., 2019) because they can affect human activities on the coast and the safe operation of projects. Sea ice can damage coastal engineering buildings and offshore facilities, crush and damage ships, and block ports and waterways (Yuan et al., 2015; Liu et al., 2019). Preventing sea ice hazards in coastal engineering has always been a focus of attention in northern China. The ice period in the Bohai Sea usually lasts three to four months during the winter season and has a certain impact on port operations in the ice area almost every winter.

As a result of the rapid development of the regional economy, the throughput of ports in the ice region has increased significantly. Although these ports play pivotal roles in facilitating growth in the Northeast Asian Economic Circle through international freight shipment, they also face increasing risks from seasonal ice hazards, which can cause damage to port infrastructure and major disruptions to port operations. Pierre and Olivier (2015) assessed the relevance of the Northern Sea Route for bulk shipping, whereas Aksenov et al. (2017) analyzed changes in sea ice in the Arctic Ocean and the navigability of arctic sea routes in the future. Nair et al. (2010) established a framework to evaluate port resilience under five disruption scenarios, including earthquakes and flooding. As a result, ensuring the safety of port infrastructure and operations in ice areas and minimizing the negative impact of sea ice hazards has always been the most pressing issue for port authorities and disaster management agencies.

Specifically, the Port of Yingkou, located in Liaodong Bay in the northern part of the Bohai Sea in China, was selected as the research subject. Although its cargo throughput has substantially increased as a result of rapid regional economic development, the port has also faced rising challenges as a result of the uncertainty of severe sea ice hazards (Liu and Chen, 2021). According to an investigation by the production management department at the Port of Yingkou, the efficiency of production, transportation, and navigation decreased by 20% in the winter of 2017 and about 25% in the winter of 2018 as a result of the impact of sea ice (Zheng, 2020). The specific effects of sea ice on shipping safety are as follows:

1. **Influence on ship speed**: The friction resistance of ships sailing in floating ice is much higher than that in water, so the speed of ships sailing in floating ice will decrease greatly. The accumulation of sea ice, especially in the thick ice area near the port, makes navigation difficult and often causes the ship’s speed to drop sharply. Sometimes, the ice is too thick to break through, and ships are stranded at sea (Fig. 1).

2. **Course stability**: Because of factors such as wind and waves, the ice layer can break up, and the broken ice can freeze together to form ice of uneven thickness. When a ship navigates through ice with varying thickness, the bow of the ship may become inclined toward the direction of thinner ice if not controlled properly by the captain. This is because the thick side of the ice creates more resistance, whereas the thin side has less resistance (Ma, 2014).

3. **Influence on berthing and unberthing**: A large amount of sea ice gathered in the harbor pool has a great impact on ships berthing and departing from the wharf. It is difficult for incoming ships to get close to the wharf and for outgoing ships to turn around. The speed of ships docking and departing is significantly slower.

4. **Channel closure**: Some of the main channels require icebreakers to break the ice before ships can sail, whereas some of the branch channels will be closed because of ice.