Marine Pollution Bulletin xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Spatial and seasonal variation of pollution sources in proximity of the Jaranman-Saryangdo area in Korea

Yeoun Joong Jung *, Young Cheol Park, Ka Jeong Lee, Min Seon Kim, Kyeong Ri Go, Sang Gi Park, Soon Jae Kwon, Ji Hye Yang, Jong Soo Mok

Southeast Sea Fisheries Research Institute, National Institute of Fisheries Science, 397-68, Sanyangilju-ro, Sanyang-eup, Tongyeong 53085, Republic of Korea

A R T I C L E I N F O

Article history:
Received 20 September 2016
Received in revised form 30 November 2016
Accepted 3 December 2016
Available online xxxx

Keywords:
Jaranman-Saryangdo area
Fecal coliform
Inland pollution
Seawater
Physicochemical factors

A B S T R A C T

We aimed to compare the spatial and seasonal distributions of fecal coliforms (FCs) and other physiochemical factors in the drainage basin of the Jaranman-Saryangdo area. Among the pollution sources, the mean daily loads and half-circle radii of FCs were the highest in June. However, the pollutants did not reach the boundary line of the designated area due to an existing buffer zone. The value of the FC geometric mean at station 1 was highest in August during periods of heavy rainfall; however, this value was lower than the regulation limit. The highest daily loads of chemical oxygen demand (COD) and chlorophyll-*a* (Chl-*a*) in seawater were in the surface layer in August; however, dissolved oxygen (DO) in the bottom water layer was at its lowest in August. This study demonstrated that season and rainfall have significant effects on the FC, COD, DO, and Chl-*a* concentrations in seawater.

1. Introduction

The Jaranman-Saryangdo area is located between the Jaran and Saryang islands on the Southern coast of Korea (Fig. 1). The Jaranman-Saryangdo area measures approximately 76 km^2, while the Jaran Bay area measures 30 km^2, (width, 5.5 km; length, 5 km), and the South part of the bay is open. A total of 9502 individuals in 4392 households and in 41-ris. reside in the drainage area surrounding the Jaranman-Saryangdo area. The total drainage area measures 131.7 km^2, of which 73.7% is a forestry field and 17.2% is cultivated fields, including rice and dry paddies (Mok et al., 2016). The Jaranman-Saryangdo area has been used to grow shellfish since May 1984, and it remains the largest oyster production area in Korea. The products are consumed domestically and are also exported to the United States, Japan, and countries in the European Union (Mok et al., 2013; Mok et al., 2014; Mok et al., 2015). Many countries, including Korea, consume raw oysters; thus, it is important to maintain suitable sanitary conditions in areas of production. The northern region of the Jaranman-Saryangdo area can be easily contaminated by various drainage sources. Fecal or chemical contamination of inland and coastal waters may have a negative impact on shellfish sanitary status (Feldhusen, 2000; Dorfman and Sinclair Rosselot, 2008), resulting in economic losses owing to shellfish bed closures (Rabinovici et al., 2004). The effect of drainage on shellfish production areas must be confirmed to protect shellfish production.

In the present study, we determined the concentrations of fecal coliforms (FCs) and physicochemical factors in seawater collected from the Jaranman-Saryangdo area on the Southern coast of Korea. Moreover, we attempted to determine the spatial and seasonal distributions of fecal coliforms (FCs) and physicochemical factors in major inland pollution sources in the drainage basin. This is the first investigation of the inland pollution sources that affect the Jaranman-Saryangdo area.

2. Methods

2.1. Sample collection

The sampling locations of the seawater and pollution sources in and near the Jaranman-Saryangdo area, including a designated shellfish production area, are shown in Fig. 1. The seawater samples used for measurement of bacteria indicative of fecal pollution were collected monthly at six stations during 2014. Sampling dates were as follows: January 20, February 19, March 18, April 21, May 19, June 16, July 22, August 18, September 15, October 27, November 17, December 15. The seawater samples were collected at a depth of 10 cm below the surface into sterilized wide-mouth bottles (250 mL) and stored in a stainless steel container. Seawater samples used to evaluate physicochemical factors were collected bimonthly from the surface and bottom water layers using a Niskin water sampler at the same six stations and same dates. Discharge samples from inland pollution sources were collected quarterly at the same dates as seawater samples during low tide at the six sampling stations to evaluate the effects of

* Corresponding author.
E-mail address: jyj3626@korea.kr (Y.J. Jung).

http://dx.doi.org/10.1016/j.marpolbul.2016.12.003
0025-326X/© 2016 Elsevier Ltd. All rights reserved.

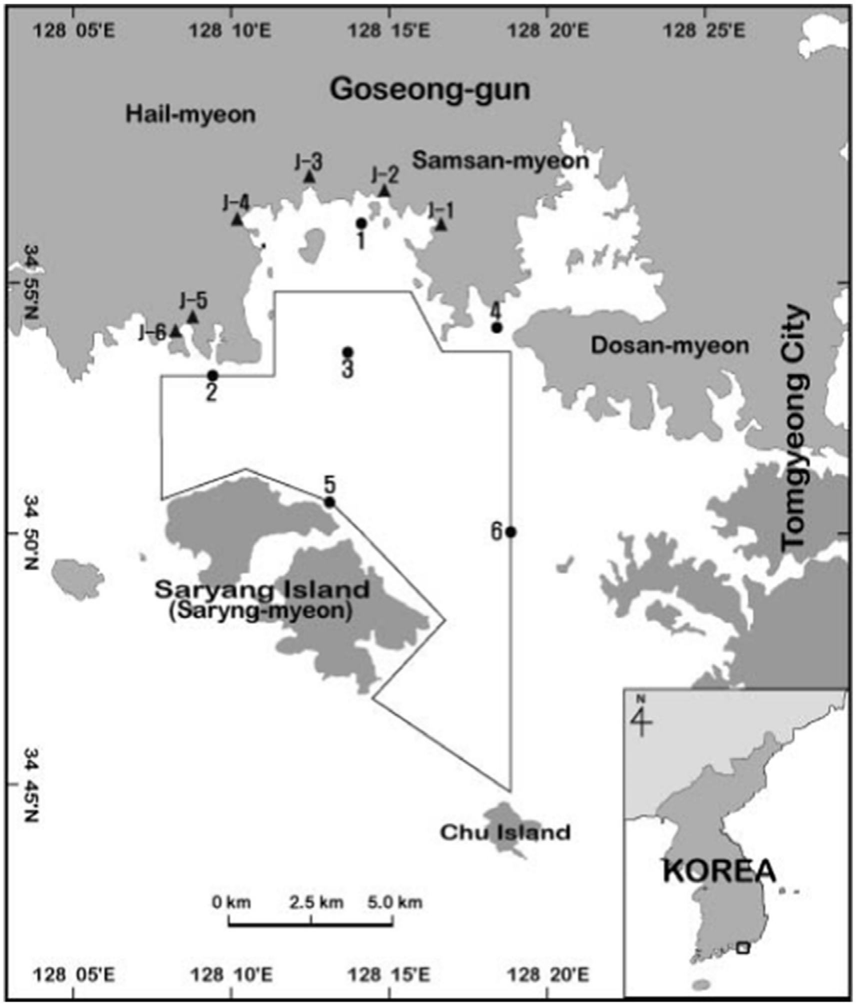

Fig. 1. Sampling locations of inland pollution sources, seawaters, and oysters from the Jaranman-Saryangdo area on the southern coast of Korea.

inland pollution sources on water quality. The samples were collected into sterilized wide-mouth bottles (250 mL) and stored in a stainless steel container. All water samples were maintained at a temperature below 10 °C during transport to the laboratory. Water temperature and salinity were measured at the depths at which the seawater samples were collected using the YSI 556 Multiprobe System (YSI, Yellow Springs, OH, USA).

2.2. Physicochemical factor analysis

The following physicochemical factors were measured: temperature, salinity, pH, dissolved oxygen (DO), dissolved inorganic nutrients, chemical oxygen demand (COD), total nitrogen, and total phosphate. In addition, the biological factor chlorophyll-a (Chl-*a*) was measured. The YSI 556 Multiprobe System (YSI) was used to measure and process the temperature, salinity, pH, and DO values onsite. Analysis of dissolved inorganic nutrients was performed according to the Marine Environmental Process Exam Standards (MOF, 2002) by filtering the samples through 0.45-μm membrane filter paper (cellulose nitrate) and subsequently measuring ammonia (NH_3), nitrate (NO_3), nitrite (NO_2) nitrogen, and dissolved inorganic phosphate (DIP) levels using a nutrient auto-analyzer (QUATTRO Four-Channel, USA). Dissolved inorganic nitrogen (DIN) was expressed as the sum of NH_3, NO_3, and NO_2 concentrations. Chl-*a* was measured using a fluorescence spectrometer (Tuner Designs 10-AU, USA) after filtering 500 mL of the sample through 0.45-μm membrane filter paper (cellulose nitrate) and extracting the dye using 90% acetone in a cold darkroom. The COD of seawater was analyzed using the alkaline permanganate method in non-filtered samples that were transported to the laboratory while frozen. COD is indicative of the content of organic compounds in a sample and is measured using a strong chemical oxidant (MOF, 2002).

2.3. Fecal bacteria analysis

Bacteriological water analysis was performed immediately after sample collection. The number of FCs in a sample was determined according to the recommended procedures for the examination of seawater and shellfish (APHA, 1970). FC counts were determined using multiple dilution series and the most probable number (MPN) method. Five tubes were used for each dilution. Lauryl tryptose broth (Difco, Detroit, MI, USA) was used as the presumptive medium. The presence of FC in presumptive positive culture tubes in which gas formed within 48 h after inoculation at 35.0 °C was confirmed using EC medium (Difco) at 44.5 °C. FC populations were expressed as MPN/100 mL.

2.4. Evaluation of inland pollution sources

The flow velocity of discharge from inland pollution sources was measured on-site using a hydrometer (Flo-Mate 2000, Marsh McBirney, Loveland, CO, USA) and the velocity-area method. The method of the Food and Drug Administration (FDA) to evaluate pollution sources was employed in accordance with the equations presented by Park et al. (2012) and Shim et al. (2012). The amount of water required to dilute