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RESEARCH

Rapid ecosystem services assessment of Mundok Ramsar wetland in Democratic People's Republic of Korea and opportunities to improve well-being

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Background: The understanding of ecosystem services can be quantified and qualitative to assess the impacts of changes in the ecosystem to support human well-being. In the Democratic People's Republic of Korea, sustainable use of ecosystem services has attracted the interest of a range of decision-makers. However, although there is a concern for biodiversity, natural ecosystem, and their services, linking ecosystems with conservation planning remains challenging.
Results: This study assessed the first qualitative ecosystem services provided by the Mundok wetland with decision makers of the West/Yellow Sea region. Furthermore, this study applied the Rapid Assessment Wetland Ecosystem method to support natural resources management, improving living conditions. We identified that cultural and supporting services index are highly provided, but preparing a plan to increase the provisioning and regulating services in Mundok wetland is necessary.
Conclusions: The assessment results can provide helpful information for ecosystem services assessment, habitat conservation, conservation planning, and decision-making at local level.

Keywords: Conservation, Mundok, Qualitative assessment, Rapid assessment wetland ecosystem services, Wetland ecosystem

Introduction

Ecosystem services (ES) have supported human beings' sustainable livelihood for many years. The concept of ES was established and the different approaches were categorized in several ways after Costanza et al. (1997). It has generated various ways to benefit and gain value from nature and apply policy and decision-making (Matzdorf and Meyer 2014; Muradian and Rival 2012; Hysing 2021; Hysing and Lidskog 2018; Schleyer et al. 2015; Verburg et al. 2016). It also provides crucial management and policy governance (Millennium Ecosystem Assessment 2005). Wetlands ES is vital for human survival (Sharma et al. 2021). They are among the world's most productive environments - cradles of biological diversity that provide the water and productivity upon which countless species of plants and animals depend for survival. Wetlands provide ES, such as increased erosion regulation, groundwater sequestration, and decreased storm water runoff amounts (Newman et al. 2020). They are also indispensable for humans, providing services ranging from freshwater supply, food, building materials, and biodiversity to flood control, groundwater recharge, and climate change mitigation. The decrease in vegetated land cover, including decreased wetlands, decreases such regulating services (Salzman et al. 2001). It affects the ecological functions of the environment and nature and people's living conditions (IPBES 2019).

According to Perrings et al. (2011) the demand for reliable information in policy-making has been highlighted as an important aspect of ecosystem evaluation. In addition, an assessment of ES is needed at the global, national, and regional levels to support decision-making (Burkhard et al. 2009; Daily and Matson 2008; Frélichová et al. 2014; Maes et al. 2012). The wetland ecosystem in the Democratic People's Republic of Korea (DPRK; also known as North Korea) is not limited by national boundaries and contributes

to the entire Korean Peninsula's ecological health. The wetland ecosystem in DPRK also provides multiple values and benefits for the environment and society. While since the 1920s, a few studies have been done on the wetlands of DPRK, this changed with the partial opening brought in the mid-1990s, when a few researchers could access the country (Chong et al. 1996; Tomek 1999; 2002). Recently, a wetland program with the Ministry of Land and Environment Protection (MoLEP) of DPRK and international partners such as the International Union for Conservation of Nature, Ramsar Regional Center - East Asia (RRC-EA), and the East Asian–Australasian Flyway Partnership (EAAFP), German political foundation started.

From the perspective of sustainable management in DPRK, the wetland ecosystem is a key provider of ES. The consequences of increased interaction among people, biodiversity, and wetland ecosystems have received considerable attention in recent years. Therefore, the conservation of wetlands and ES assessment are to be a concern in DPRK. MoLEP, with international organizations, carried out an intensive program to raise awareness of wetlands and their fauna and flora, particularly migratory birds, build capacity for managers of wetlands and environmental administrators, and integrating the wetland in DPRK into the network of wetland protection in Northeast Asia and beyond (EAAFP 2020; ESP 2018; IUCN Asia 2018; RRC-EA 2018). As a result, wetlands protected areas in DPRK increased from 34 sites in 1996 (Chong et al. 1996) to 54 sites in 2018 (Ri et al. 2018).

On the other hand, the most extensive wetland habitats globally, tidal flat along the Korean West Sea in the Yellow Sea region, has been under pressure such as reclamation, aquaculture and over-exploitation of intertidal resources (Moores et al. 2016; Murray et al. 2014; Murray et al. 2015). However, there has been no environmental impact assessment of wetlands in DPRK. Moreover, while assessing the current and potential value of wetlands have been increasingly recognized in the context of wetland ecosystem conservation, ES assessment has rarely been considered in DPRK due to limited approaches and access to the site. Thus, we assessed ES provided by wetland ecosystems at local and relevant scales. Our assessment was based on the existing method of the RRC-EA (2020), the regional initiatives formally recognized by the Ramsar Convention. Our key focus is to evaluate and analyse available ES to help support management decisions, policy-making and applying complex decision-making for wetland conservation.

Materials and Methods

Study site description

The terrain of DPRK is mostly forest ecosystem, approximately 70% of the territory. However, wetlands and marine ecosystems are covering the rest of the area. The wetland ecosystem covers 2,433 rivers, 705 streams, and 2,700 lakes, including artificial reservoirs, marshes, and paddy (Ri et al. 2018). The tideland of the Korean West Sea is the largest wetland ecosystem. Our study area covered the Mundok migratory bird reserve along the Korean West Sea, the Ramsar site, 3,715 ha (Fig. 1). The Mundok Ramsar site is important for human well-being and ES. The area is the most productive environment and reservoir of biodiversity, which supplies essential services upon which numerous species of plants and animals thrive.

Rapid assessment wetland ecosystem services

Rapid assessment wetland ecosystem services (RAWES) are a rapid and straightforward method for assessing ES at the 13th Meeting of the Conference of the Contracting Parties to the Ramsar Convention adopted Resolution XIII.17. RAWES apply assessment supported by ecosystem to the Ramsar site information sheet under the Ramsar convention, incorporating nature features and describing the ecological character of a wetland (RRC-EA 2020). RAWES also can be adapted as appropriate to satisfy the relevant

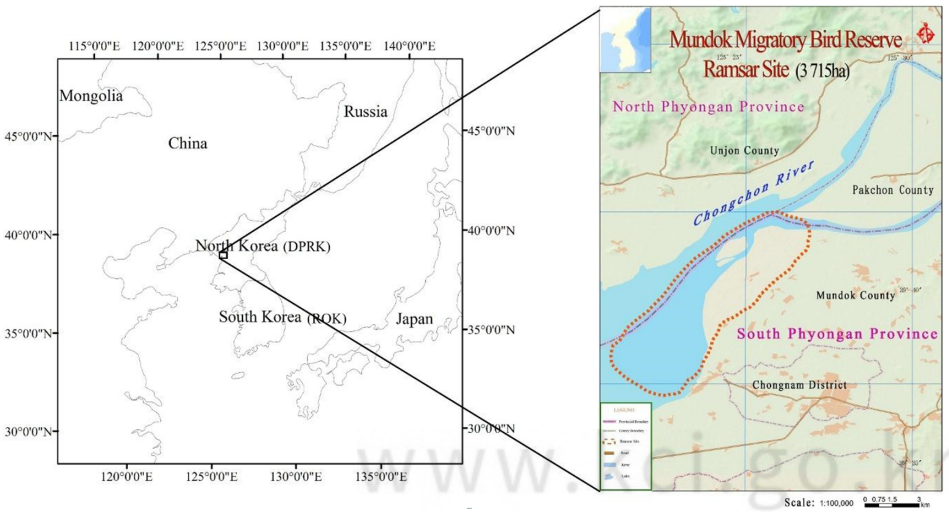

Fig. 1 Study area. Source: our own compilation, based on the map of Ramsar Sites Information Service (2018).

situation to assess the wetlands ES. For example, McInnes and Everard (2017) applied RAWES over 60 different wetland sites supporting development of a wetland strategy for the Metro Colombo Region, Sri Lanka. The study combined the results of training, and local assessors using a variety of field indicators to assess the positive or negative contribution. It was considered 36 indicators to evaluate the RAWES: 10 provisioning services, 15 regulating services, 7 cultural services, and 4 support services.

We classified wetland ES into 4 services proposed by Millennium Ecosystem Assessment (2005) as follows: provisioning services such as freshwater, genetic resources, energy harvest; regulating services such as air quality, local climate regulation, water regulation, disease regulation; cultural services including cultural heritage, recreation and tourism; and supporting services such as soil formation and nutrient cycling. Each ES is assessed using a relative scale, significant positive contribution (++), positive contribution (+), negligible contribution (0), negative contribution (–), and significant negative contribution (––) from Defra (2007), RRC-EA (2020). In this study, 33 items were evaluated and highlighted during the training on wetland management for 25 site managers from People's Republic of China and the two Korea of the West/Yellow Sea in 2018: 10 provisioning services, 14 regulating services, 8 cultural services, and 5 support services. The indicators for assessment per services were chosen by decision-makers in DPRK during the training in 2018. It also considered the ecological characteristic in Mundok wetland. Based on the results of RAWES, we also applied the ES index (ESI) and we observed ecosystem service production formulation, to quantify and analyse Mundok wetland ES, as shown in the following formula (RRC-EA 2020).

$$ESI = \frac{\sum(n_{+1.0} + n_{+0.5}) + \sum(n_{-1.0} + n_{-0.5})}{\sum n_{Total}}$$

where, ESI is the ecosystem services index used to all positive scores (+1.0 and +0.5) and all negative scores (–1.0 and –0.5).

Results

Rapid ecosystem services assessment in Mundok wetland

We identified ES's value, which primarily benefits the local people in the Mundok wetland. Table 1 shows the qualitative results of ES value with function in the Mundok wetland. As a result of provisioning services evaluation, a particular great benefit is the food, fuel, fiber, natural medicines, ornamental resources, clay, mineral, aggregate harvesting, and energy harvest. In the regulating services, major benefits are local climate regulation, water regulation, erosion regulation, and fire regulation. Most of the cultural and supporting services were evaluated as positive contributions (++ or +) than those making a negative contribution. However, the waste disposal of provisioning services and pest regulation of regulating services are disadvantages in Mundok wetland. The assessment results demonstrated by the cultural and supporting services show significant benefits and need management planning. For instance, the constant recycling of groundwater supports the development and formation of soils. The cycling of soils helps the habitats, and transpiration from rice paddy fields also plays a vital role in the water cycle in Mundok wetland. However, household sewage and agricultural wastes are underlying causes of water contamination in Mundok wetland.

The site supports the habitat for internationally threatened species such as Scaly-sided Merganser (*Mergus squamatus*), Baer's Pochard (*Aythya baeri*), Spoon-billed sandpiper (*Calidris pygmaea*), Black-faced Spoonbill (*Platalea minor*), Red-crowned Crane (*Grus japonensis*), and Swan Goose (*Anser cygnoides*). The Mundok wetland is typically an important stopover place for Swan Goose and Red-crowned Crane. There are several reasons for the great importance of Mundok wetland to wild birds and biodiversity conservation. The area is extensive, with a high diversity of habitats so that it can support many different species. The Mundok wetland is also highly productive, as indicated by a large number of waterbirds. Although much of the lakes' land is farmed, disturbance levels are relatively lower than in many wetlands elsewhere in East Asia. The geographical location of the area means that the Mundok wetland is likely used by birds that have wintered further southwest. In addition, it is an international hub for migrant birds. Therefore, Mundok wetland has a special responsibility to preserve habitats for birds living in the country and migrating on EAAFP.

At the same time, nature protection issues on the Korean Peninsula have always been of interest as they are part of its exciting culture and natural assets. Therefore, the preservation or, where necessary, restoration of valuable habitats in DPRK is important to preserve the country's natural assets. Still, it can also be used to create new interest in the country as nature-based tourism, including eco-tourism destinations in the long run. But this requires joint efforts of Korean and international experts, academics, managers, non-governmental organizations, and the population to conserve the environment. Based on this significant biodiversity characteristic, the Mundok wetland is designated as a natural monument Mundok Red-crowned Crane habitat, the first Ramsar site, and EAAFP site in DPRK. Furthermore, in 2019, the first Mundok Swan Goose festival as part of cultural services was held with local people.

Ecosystem services index of Mundok wetland

As a result of the mean of ESI assessment, the cultural

Table 1 The results of the Mundok wetland ecosystem services assessment

Ecosystem services		Rank	Description
Provisioning	Fresh water	+	The river provides irrigation water to the nearby agricultural farms.
	Food	++	Cultivating the land is used for food production, while the water ponds nearby. The estuary is used for aquacultures, such as fish, shrimps, and shellfish.
	Fuel	++	A large amount of brown coal deposit is effectively used for house heating and industrial raw materials.
	Fiber	++	Reeds harvested from the estuary and riverbank ans are used as raw materials for the fiber and also used as a building material.
	Genetic resources	+	The site supports 200 species of birds, 20 species of animals, 20 species of reptiles, 60 species of fish, tens species of sea-floor animals, 44 species of *Annelida, Mollusk,* and *Crustacea.*
	Natural medicines	++	Carp, shellfish, mud-snail, and other resources are used as natural medicines and medical materials.
	Ornamental resources	++	Reed mattresses and baskets increase the local economic opportunities in the reserve.
	Clay, mineral, aggregate harvesting	++	Brown coal and clay are extracted from the underground pit and collapsed areas.
	Waste disposal	–	Household sewage and agricultural wastes are underlying causes of water contamination.
	Energy harvest	++	The site is a potential site for tidal and wind energy generation.
Regulating	Air quality regulation	+	Aquatic lives and riparian vegetative cover contribute to the local air quality regulation.
	Local climate regulation	++	The river estuary and the nearby water ponds play an important role in the microclimate regulation.
	Global climate regulation	+	The wetland ecosystem structure contributes to emission reduction and carbon storage.
	Water regulation	++	The water caused by the flood is stored in the landfall water pools and marshes and slowly discharged into the sea. Or they can be effectively used during the drought season.
	Flood hazard regulation	+	Reed and water ponds near the estuary act as buffer zones to reduce the natural disaster risk of floods, heavy storms, and drought.
	Pest regulation	–	Water ponds and reed provide suitable habitat and breeding conditions for the insects such as mosquitoes.
	Disease regulation - human	+	Aquatic lives purify the water quality while the reptiles and birds eat the insects that spread the pathogenic disease.
	Erosion regulation	++	Vegetative cover plays an essential role in soil erosion.
	Water purification	+	The pollutants and substances that might cause eutrophication are mostly self-purified due to aquatic life and water cycling processes through landfall water ponds and marsh, and reed downstream of the river.
	Pollination	+	Insects such as butterflies, bees, and dragons help pollinate crops and other plants.
	Salinity regulation	+	The large area of reed reduces the water's salinity from the sea.
	Fire regulation	++	Landfall water ponds and irrigation channels reduce fire outbreak/spread risk.
	Noise/visual buffering	0	The site has to consist of paddy fields, which generate less noise pollution.
Cultural	Cultural heritage	++	Designated as National Natural Monument, International Crane Network Site, Ramsar Site, EAAFP Network Site.
	Recreation and tourism	++	It is a potential site for birdwatching and eco-tourism. Local as well as people from the city and adjacent towns enjoy picnic in Mundok.
	Aesthetic value	+	Diverse wetland ecosystems in harmony with rice paddy fields; and hundred of thousand of migratory birds roosting, feeding and flying make the spectacular scenery of Mundok.
	Social relations	++	Local communities are engaged in diverse activities such as cultivation, fish farming, mining industry, and biodiversity conservation.
	Educational and research	++	Regular monitoring and surveys on biodiversity (e.g. migratory birds) and hydrology are conducted in the Reserve.
Supporting	Soil formation	++	The accumulative island in the estuary, soil formation by the Chongchon and Taeryong rivers is constantly taking place.
	Primary production	+	Estuary and nearby wetland are played an important role in the primary production of the photosynthesis.

Table 1 Continued

Ecosystem services	Rank	Description
Nutrient cycling	++	Nutrient cycle and nitrogen-fixing are taking place by the micro-organism and soil insects.
Water recycling	++	The water constantly recycles through the evaporation from the swamps, water pools stored in the river, or the evaporation from the seawater. In addition, transpiration from rice paddy fields also plays an important role in the water cycle.
Provision of habitat	++	The site supports 200species of birds, 20 species of animals, 20 species of reptiles, 60 species of fish, tens species of sea-floor animals, 44 species of *Annelida, Mollusk* and *Crustacea*.

++: significant positive contribution; +: positive contribution; 0: negligible contribution; –: negative contribution.

and supporting services were higher than other services. The provisioning services were 0.58, the regulating services were 0.54, the cultural services were 0.90, and the supporting services were 0.90. We also examined means of standard errors (SE) of the scores estimated from each service and found that provisioning services were 1.39, the regulating services were 0.90, the cultural sand supporting services were 0.78 as presented in Figure 2. The provisioning and regulating services index were relatively higher than other services in the percentage of the services produced out of the total in ES; provisioning services at 31.91%, regulating services at 29.79%, cultural and supporting services at 19.15%. We identified that it is necessary to prepare a plan to increase the provisioning and regulating services. The area is that food production from the paddy rice cultivation area, aquacultures, and marine resources take most of the local industry and livelihood. In addition, the reed area also regulates carbon balance, and the rivers – Chongchon and Daryong rivers provide irrigation water to the people in the Mundok area. The reinforcement of provisioning and regulating services in the Mundok wetland management plan could be prepared.

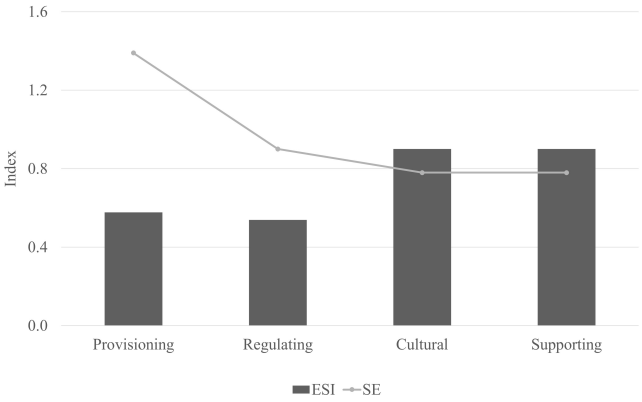

Fig. 2 The results of the Mundok wetland ecosystem services index (ESI). SE, standard error.

Discussion

The place-based participatory ES assessment is becoming significant and has been applied to identify the location that ES provide (Kim et al. 2021; McInnes and Everard 2017; Potschin et al. 2013). Despite the increasing understanding of the benefits that the wetlands in DPRK provide, a lack of studies has been undertaken to fully understand the interconnected range of ecosystem services and the distribution of benefits. In this study, we first assessed the wetland ecosystem by underlying provisions of ES in DPRK. Our approach followed the site-based rapid assessment by RRC-EA (2020). The assessment evaluated complex ecological conditions using a finite set of observable field indicators (Stein et al. 2009). The evaluation was based on the trained indicators to assess the positive or negative contribution. It also comprehensively assessed the plurality of benefits a wetland provides that can be considered, involving limited resources in McInnes and Everard (2017), Kim et al. (2019) and Kim et al. (2021), who used similar research methodologies. It provided a detailed qualitative assessment presented as a method that meets the needs of wetland sites supporting the development of wetland management at the local level in DPRK. This study evaluated services that could be used to understand the importance of providing society with benefits from ES and managing the wetland. The results can provide the information needed to identify the benefits of the wetland at the local and national levels.

Furthermore, this assessment offers a flexible classification by ES-provisioning and regulating services, critical for green infrastructure, and cultural and supporting services, significant for ecological contexts. In addition, the assessments can be linked to the value of ecosystem services. This approach can help us determine nature-based assessment steps to evaluate ecosystem services. According to Ri et al. (2018), the present threat in Mundok wetland is excessive reed and marine production of local people due to direct influence on the feeding and breeding of waterbirds. The findings in this study suggest an idea of benefits provided by Mudok wetland to solve the present threat and improve living and financial conditions for local people. The Mundok wetland will offer multiple benefits for local people and decision-makers, including enhancement of management practices, giving a chance to deliver engage-

ment activities on-site through the international environment network e.g., EAAFP partnership, Wetland Link International.

To conserve Mundok wetland habitat and link with people, we suggest that nature-based tourism with birdwatching could provide a helpful concept on the interdependence of people and nature, considering the ES and how to utilize ecosystem resources best sustainably. The value of bird count data to policy-makers and decision-makers is explicit in much of the scientific conservation literature, such as Kim et al. (2016), Su and Zou (2012). It is implied through the texts of the international agreements including Convention on Biological Diversity and the Ramsar Convention Criteria, which use the number of waterbirds counted at a wetland and the percentage of the population of a waterbird species counted at wetland in the identification of internationally important wetlands. The Mundok wetland supports globally threatened and vulnerable species habitats such as Scaly-sided Mergansers (Duckworth and Chol, 2013), Black-faced Spoonbill, and Swan Goose (Chong et al. 1996; Tomek 1999;2002; Ri et al. 2018). It is also possible that the species are presently breeding and migrating to the south (Choi et al. 2020). Migratory birds' potential value in nature-based tourism programmes, the presence or absence, rarity or abundance of migratory birds often provides valuable insights into the health and biological productivity of the places where they are found – helping to identify national and international biodiversity hotspots and inform management strategies aimed at sustainable development. However, given the rapid ES assessment of this study, there are a few limitations. We conducted the qualitative assessment of ecosystem services that could be easily measured and included in RAWES. The mapping and quantifying ES can be an effective means to monitor and manage ecosystems (Burkhard et al. 2012).

The quantification assessment could provide helpful information for integrated wetland ecosystem management and decision-making. Therefore, future studies should conduct quantification assessments based on field observation data or apply quantification modelling with indicators used to quantify wetland ES. There is also increasing in wetland ES concepts and approaches as blue carbon. The Mundok wetland is a coastal wetland in the Korean West sea and Yellow sea eco-region. It is important to identify the site of high-density ES. There is a need to consider hotspots or priority areas regarding their efficiency, abundance, and relative rankings in expert-based estimations (Choi et al. 2018; Christin et al. 2016). However, this study focused on assessing the ES of simple methodologies for application at the local level. An approach to wetland ES assessment that considers the entire ecosystem at national level is needed.

Conclusions

ES assessment has a primary role in informing policy and decision-making. The evaluation impact of ES assessment is a significant source of evidence for future decision-making. ES assessment is now broadly applied in complex decision-making; it includes various methods and standards, but the optimization of assessment is still a work in progress. The range of ES quantified and qualified, and the ability to provide reliable information for decision-making should be considered a priority. Therefore, the process needs to determine how ES impact will be assessed and how the implications interact. In addition, ES assessment has various aims, and quantitative or qualitative assessments are required for natural resource management policy-making. An ES approach is essential to assess biodiversity and support natural ecosystem conservation. This approach can help us select conservation areas or spots and inform decision-making processes.

The Mundok wetland is internationally important for biodiversity conservation, and ecological health is vital to improve well-being. It has been designated as the first Ramsar Site and EAAFP site of international importance when DPRK acceded the Ramsar Convention and EAAFP in 2018. To conserve the Mundok wetland, strengthen the positive national and international ecosystem, and help protect local people's livelihoods, we assessed Mundok wetland ES. We provided the first application of RAWES for qualitative the Mundok wetland ecosystem at the local level in DPRK, using the rapid and straightforward method. The approaches suggested, and results in this study can influence decision-making to support wetland ecosystem conservation and management plan. The ES assessment can be linked to the value of ES in Mundok. This approach can also help the decision-makers in DPRK determine nature-based assessment steps to evaluate ecosystem services. However, we need future research through appropriate structures and mechanisms such as quantification and mapping ES using spatial data at the national level and beyond. It also needs to consider socio-economic elements for actual benefits to humans' well-being based on the Driver-Pressure-State-Impact-Response framework (Holten-Andersen et al. 1995).

Abbreviations

ES: Ecosystem services
ESI: ES index
Defra: Department for Environment, Food and Rural Affairs, UK
DPRK: Democratic People's Republic of Korea
MoLEP: Ministry of Land and Environment Protection
RRC-EA: Ramsar Regional Center - East Asia
EAAFP: East Asian–Australasian Flyway Partnership
RAWES: Rapid assessment wetland ecosystem services
SE: Standard error

++: Significant positive contribution
+: Positive contribution
0: Negligible contribution
–: Negative contribution
––: Significant negative contribution

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Authors' contributions
HAC did conceptualization, methodology, performed analysis, data curation, wrote the manuscript, and obtained funding. BS and DH did conceptualization, review and editing. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable requests.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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