# Identification of biological and physicochemical parameters of salt pond lands in Pati Regency, Central Java, Indonesia

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**Abstract**. The coastal area is a transition zone that can be used by various marine biota to support their lives. The aim of this study was to determine the abundance of plankton and gastropods in traditional and integrated saltwork pond lands. This research was conducted from March to November 2020 in Pati Regency, Indonesia, with 8 locations consisting of 4 locations in traditional systems and 4 locations in integrated systems. A statistical analysis using the Principal Component Analysis (PCA) was performed to reveal the relationship between the saltwork system and the abundance of plankton and gastropods. The PCA results showed that under conditions of dust substrate and high Pb content, a high abundance of *Stenothyra ventricosa* and zooplankton was found. The higher dust substrate resulted in a higher abundance of phytoplankton. Meanwhile, a higher specific gravity resulted in a lower abundance of *S. ventricosa* in the integrated system. The results showed that the type of plankton found in the integrated and traditional systems was *Nitzschia* sp. and the type of gastropod found in both saltwork systems was *S. ventricosa.* The types of plankton and gastropods can be used as indicators of the saltwork systems, both traditional and integrated. In addition, it is necessary that the sedimentary soil conditions in the integrated system have ideal dust conditions of 81-95.8%. The integrated system has advantages, in terms of salt specific gravity, but also in terms of species diversity, which are markers of the saltwork ecosystems quality.
**Key Words**: molluscs, plankton, integrated system, traditional system, Pati Regency.

**Introduction**. Saltwork ponds are a very important means of supporting the salt production. Salt is an important component at the industrial and household scales, that is used in the food processing. As the community demand for salt continues to increase from time to time, a good pond system in terms of management and production is needed. Traditional systems and integrated systems certainly have their respective advantages and disadvantages in terms of production quality. The saltwork integration program is one way to reduce the chance of seawater intrusion into the ground because the crystallization table plot uses a geo-isolator. Ecologically, the saltwork process has a related relationship water-sediment. Water can be used as a place to live for plankton while sediment is used as a habitat for gastropods. The saltwork process requires the presence of sea water. As water evaporates and salinity increases, when a sufficient volume of water is pumped the salinity in a pond can be maintained at a constant value (Carlos Pedros-Alio et al 2000). Geographic location and water quality in supporting the saltwork system are also important. This is due to the required volume of clean sea water in large quantities (Costa et al 2015).

The biological parameters used in the identification of the saltwork system are plankton and gastropods. There are 2 types of plankton that are often found in the ecosystems, i.e., phytoplankton and zooplankton. Plankton growth and reproduction are influenced by various factors, i.e., physical and biogeochemical variations (Liu et al 2021), nutrient availability (Campbell et al 2013), environmental conditions (Ji et al

2021) and upwelling systems (Otero et al 2020). Plankton can also be used as a location prediction for fishing areas (Evans & Pepin 1989). One of the keys to observing the pelagic zone is to estimate the plankton presence (Batten et al 2019).

From another perspective, identification of saltwork biological parameters through sediments can be performed in the presence of gastropods. Gastropods are usually found in aquaculture sediment sites. Therefore, gastropods can also live and breed in the saltwork area. Gastropods are able to survive in high salinity conditions (Ho et al 2021). In addition, mangrove ecosystems are associated with gastropods (Ariyanto et al 2018). The aim of this study was to determine the comparison of physicochemical and biological parameters as indicators for traditional and integrated saltwork pond lands.

## Material and Method

***Description of the study sites***. This research was conducted at 8 locations in the saltwork system, i.e., 4 traditional saltwork systems and 4 integrated saltwork systems. Both the traditional and integrated system were located in Raci Village, Batangan Subdistrict (6'35'32S, 111'5'30E); Genengmulyo Village, Juwana Subdistrict (6'41'34 S, 111'7'42E); Tluwuk Village, Wedarijaksa Subdistrict (6'40'49S, 111'6'38E); Kertomulyo Village, Trangkil Subdistrict (6'40'34S, 111'5'20E). Data analysis on the gastropod identification was performed at the Fish and Environmental Resources management Laboratory, Faculty of Fisheries and Marine Sciences, Diponegoro University, Indonesia.

***Data collection***. It included data on biological parameters, i.e., the abundance of plankton and gastropods, data on environmental parameters, i.e., water quality and sediment texture at 4 research locations of traditional and integrated saltwork systems.

***Plankton abundance***. Plankton was collected at the locations of the integrated and traditional using a plankton net. Plankton samples were put into 250 mL sample bottles. The samples were identified and analyzed for abundance using a Sedgwick-Rafter count at the Fish Health Laboratory, Central Java, Indonesia. The plankton abundance was calculated using the following formula (SNI 1995):

$$N = l/p \times q \times I/v$$

Where:
N - abundance (cells $L^{-1}$);
*l* - number of samples/plankter in the sub-sample;
*p* - volume of sub-sample;
I - volume of sample;
v - volume of filtered water.

***Gastropod abundance***. Abundance was the number of gastropods found in the sampling area. Sampling of gastropods was performed using a square box with the edge of 20 cm placed in the saltwork systems, both traditional and integrated systems.

$$K = A / L$$

Where:
K - abundance;
A - number of gastropods;
L - quadrant area.

***Physicochemical parameters***. These parameters consisted of sediment texture, water quality including temperature, specific gravity, ammonia and lead (Pb) contents. For Pb, a 20 g testing sample was prepared. The sample was dissolved in distilled water and analyzed using an atomic absorption spectrophotometer (AAS) with a maximum wavelength of 283 nm for Pb (SNI 2017).

Sediment texture analysis was performed and soil samples were collected using a brass (copper) tube. The soil was excavated to a certain depth (5-10 cm) around the

copper tube. Sediment texture analysis was conducted using the pipette method. Water quality measurement included temperature, specific gravity (a measure of the salinity on the Baumé scale), ammonia and Pb contents. Temperature measurements were carried out directly, while the specific gravity and Pb measurements were performed at the Fish Health and Environmental Laboratory, Agency of Fisheries and Marine Affairs, Semarang Province. A measurement of the specific gravity of salt using an odor meter was conducted in situ at the locations of traditional and integrated systems.

***Statistical analysis***. A Principal Component Analysis (PCA) was performed using Xlstat 2021. This PCA analysis revealed the physicochemical and biological parameters of both traditional and integrated saltwork systems.

## Results and Discussion

### *Biological parameters*

***Plankton abundance***. The results of the sample identification and plankton abundance calculation from the crystallization table plots are presented in Table 1. Five species of phytoplankton were found in the integrated saltwork system, i.e.: *Nitzschia* sp., *Oscillatoria* sp., *Trachelomonas* sp., *Brachionus* sp., *Chlorella* sp., while the identified species of zooplankton was *Brachionus* sp. The species of phytoplankton found in the traditional system were: *Nitzschia* sp., *Trachelomonas* sp., *Oscillatoria* sp. and *Tetraselmis* sp. The phytoplankton the most frequently found in the integrated and traditional systems was *Nitzschia* sp. There were two species of zooplankton found in the integrated saltwork system, i.e.: *Cyclops* sp. and *Brachionus* sp., while the traditional system had only one species, i.e. *Brachionus* sp.

Table 1

Types and abundance of plankton in the integrated and traditional saltwork systems in Pati Regency, Central Java, Indonesia

| *Saltwork* | *Type* | | *Density (x 1,000 cells mL$^{-1}$)* | |
|---|---|---|---|---|
| | *Phytoplankton* | *Zooplankton* | *Phytoplankton* | *Zooplankton* |
| SI1 | *Nitzschia* sp.<br>*Oscillatoria* sp. | - | 0.433 | 0 |
| ST1 | *Nitzschia* sp.<br>*Trachelomonas* sp.<br>*Oscillatoria* sp. | *Brachionus* sp. | 0.83 | 0.03 |
| SI2 | *Nitzschia* sp.<br>*Trachelomonas* sp.<br>*Brachionus* sp. | - | 0.43 | 0.03 |
| ST2 | *Nitzschia* sp.<br>*Trachelomonas* sp.<br>*Oscillatoria* sp. | - | 0.46 | 0 |
| SI3 | *Nitzschia* sp.<br>*Oscillatoria* sp.<br>*Chlorella* sp. | *Cyclops* sp. | 0.033 | 0.03 |
| ST3 | *Tetraselmis* sp. | - | 0.2 | 0 |
| SI4 | *Nitzschia* sp.<br>*Oscillatoria* sp. | *Brachionus* sp. | 1.1 | 0.03 |
| ST4 | *Nitzschia* sp.<br>*Oscillatoria* sp. | - | 0.83 | 0 |

SI-integrated system; ST-traditional system; 1-Raci Village, Batangan Subdistrict; 2-Genengmulyo Village, Juwana Subdistrict; 3-Tluwuk Village, Wedarijaksa Subdistrict; 4-Kertomulyo Village, Trangkil Subdistrict.

The presence of phytoplankton species was found to be higher than zooplankton on the integrated saltwork land than on traditional land, due to the water parameters stability in the integrated system, compared to the traditional system. The increase of the salt

content affected the decrease of the species diversity and the density/abundance of plankton. The higher salinity results in less organisms in the water, due to their limited adaptability. Plankton serves as the basis of food webs and it is vital for other organisms. Plankton density is also influenced by the anthropogenic activity, resulting in habitat changes (Malik & Bharti 2012) and climate change (Henson et al 2021).

***Gastropod abundance***. Table 2 shows the differences in the abundance of gastropods in traditional versus integrated systems. The integrated system had the highest abundance of gastropods, compared to the traditional system. In the integrated system, 6 types of gastropods were found, i.e.: *Stenothyra ventricosa*, *Sermyla riquetii, Terebralia palustris*, *Cerithidea quadrata*, *Turritella terebra* and *Polinices mammilla*. Meanwhile, 5 types of gastropods were found in the traditional system, i.e., *S. ventricosa*, *T. palustris*, *T. terebra*, *S. riquetii*, *P. mammilla*.

Table 2

Types and abundance of gastropods in the integrated and traditional saltwork systems in Pati Regency, Central Java, Indonesia

| *Location* | *Type* | *Abundance (ind m$^3$)* |
|---|---|---|
| SI1 | *Stenothyra ventricosa* | 14.150 |
| | *Sermyla riquetii* | 48 |
| ST1 | *Stenothyra ventricosa* | 12.550 |
| | *Terebralia palustris* | 175 |
| | *Turritella terebra* | 150 |
| | *Sermyla riquetii* | 400 |
| SI2 | *Stenothyra ventricosa* | 16.575 |
| | *Terebralia palustris* | 100 |
| | *Cerithidea quadrata* | 25 |
| ST2 | *Stenothyra ventricosa* | 3.225 |
| | *Terebralia palustris* | 50 |
| | *Polinices mammilla* | 75 |
| SI3 | *Stenothyra ventricosa* | 33.625 |
| | *Terebralia palustris* | 50 |
| | *Sermyla riquetii* | 150 |
| ST3 | *Stenothyra ventricosa* | 10.850 |
| SI4 | *Stenothyra ventricosa* | 2.700 |
| | *Turritella terebra* | 125 |
| | *Polinices mammilla* | 50 |
| ST4 | *Stenothyra ventricosa* | 575 |

SI-integrated system; ST-traditional system; 1-Raci Village, Batangan Subdistrict; 2-Genengmulyo Village, Juwana Subdistrict; 3-Tluwuk Village, Wedarijaksa Subdistrict; 4-Kertomulyo Village, Trangkil Subdistrict.

*S. ventricosa* was the most abundant species in both traditional and integrated systems, however, it found to be more abundant in the integrated system, in particular at the location of Tluwuk Village, Wedarijaksa Subdistrict: 33.625 ind m$^{-3}$, while in the traditional system it was of 2.510 ind m$^{-3}$. In the integrated system, the species *C. quadrata*, a type of mangrove gastropod, was also found. This is in accordance with a research on the gastropod species *C. djadjariensis*, found at the mangrove locations (Ariyanto et al 2020).

***Physicochemical parameters***

***Soil texture***. Soil texture is one of the important factors determining the success of the saltwork integration. In contrast to the saltwork integration, the soil type does not really affect the salt production process. The results of soil texture measurements on the integrated and traditional saltwork lands are presented in Figure 1.

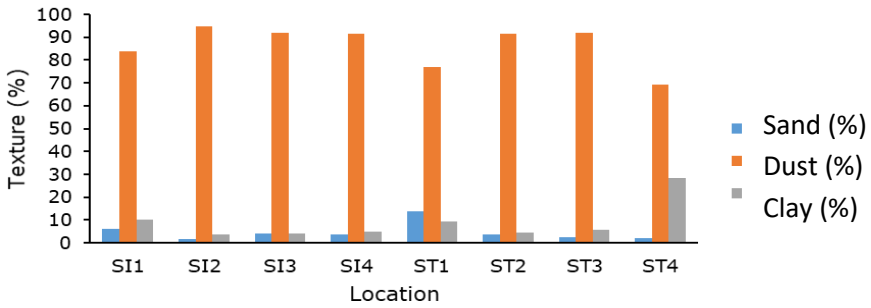


Figure 1. Distribution of soil texture measurement results in the traditional and integrated saltwork systems in Pati Regency, Indonesia (SI-integrated system, ST-traditional system, 1-Raci Village, Batangan Subdistrict, 2-Genengmulyo Village, Juwana Subdistrict, 3-Tluwuk Village, Wedarijaksa Subdistrict, 4-Kertomulyo Village, Trangkil Subdistrict).

Figure 1 shows that the soil texture of the saltwork integrated and traditional land is dominated by dust, in the range of 81-95.8% at the integrated system and in the range of 69.4-91.9% at the traditional system. The highest percentage of clay fraction was found on the integrated land of Genengmulyo Village (94.8%), on the traditional land of Tluwuk Village (91.9%) and on the integrated land of Tluwuk Village (91.8%). The highest percentage of sand fraction in the traditional land of Raci Village was of 14%, in the integrated land of Raci Village it was of 6.1%, and in the integrated land of Tluwuk Village it was of 4.0%. The lack of sand and clay content and the large amount of dust content define a pond soil with small porosity. Porous soils have a greater permeability. Less permeable soils are more suitable for saltwork ponds, since they have the ability to store water for salt production. This is in line with Kurniawan & Zulham (2020), stating that the production process of salt is influenced by the soil permeability and relies on the water exposure to the sunlight. The saltwork pond soil at the research location had a small permeability and a small porosity, so the chance of salt pond water intrusion into the ground is small. Nguyen et al (2019) added that the use of geo-isolators can reduce the saltwater intrusion into the soil. Generally, all locations showed the condition of dust texture. The suitability laboratory test results of the soil texture in Genengmulyo Village and Bakaran Kulon Village, Juwana Subdistrict, Pati Regency, showed that the dust texture was quite suitable for salt ponds.

***The specific gravity level***. Table 3 shows the values of 3 observations (in the morning, afternoon and evening) of the specific gravity at the integrated and traditional saltwork locations: the integrated system had a higher content than the traditional system. The specific gravity, measured in degrees Baumé (°Be), ranged from 18.82 to 21.76°Be in the integrated system, while in the traditional system it ranged from 17.12 to 18.88°Be.

Table 3

Specific gravity measurement results in Baumé degrees (°Be) at the research locations in Pati Regency, Central Java, Indonesia

| *Location* | *Observation* | | |
|---|---|---|---|
| | *a* | *b* | *c* |
| SI1 | 22.12 | 23.82 | 23.88 |
| SI2 | 20.18 | 20.65 | 21.76 |
| SI3 | 19.35 | 17.53 | 18.88 |
| SI4 | 18.82 | 19.32 | 20.12 |
| ST1 | 19.88 | 20.35 | 20.45 |
| ST2 | 18.76 | 18.88 | 19.05 |
| ST3 | 17.12 | 17.82 | 18.56 |
| ST4 | 18.06 | 18.59 | 19.25 |

SI-integrated system; ST-traditional system; 1-Raci Village, Batangan Subdistrict; 2-Genengmulyo Village, Juwana Subdistrict; 3-Tluwuk Village, Wedarijaksa Subdistrict; 4-Kertomulyo Village, Trangkil Subdistrict; a-morning; b-afternoon; c-evening).

The measurement results of the specific gravity at each location, at different times, showed an increase. The specific gravity in the integrated system was higher than in the traditional system: it ranged from 18.82 to 23.88°Be in the integrated system and from 17.12 to 19.25°Be in the traditional system. In terms of time, it is shown that towards the afternoon, the specific gravity increased due to the sunlight, which determined the salt accumulation. The results of this study are in line with the research conducted by Sartono et al (2013) measuring the salt production process in a courtyard plot: the minimum salinity of the inlet water used ranged between 15 and 25°Be. The harvested salt has a specific gravity of 25-27°Be, according to Mani et al (2012).

***Ammonia and lead (Pb) contents***. Intercropping is a characteristic of the salt production lands in Pati Regency. The salt production takes place during the dry season for 4-5 months, and the rainy season is used for the milkfish cultivation. The measurement results showed that the ammonia content in the integrated and traditional saltwork land was 0. This reflects that the water condition for salt production was within the specified quality standards. The water content of Pb came from human activities affecting the seawater. The sampling for the Pb measurements was performed on the crystallization table. The Pb measurement results in the integrated and traditional saltwork lands are presented in Figure 2.

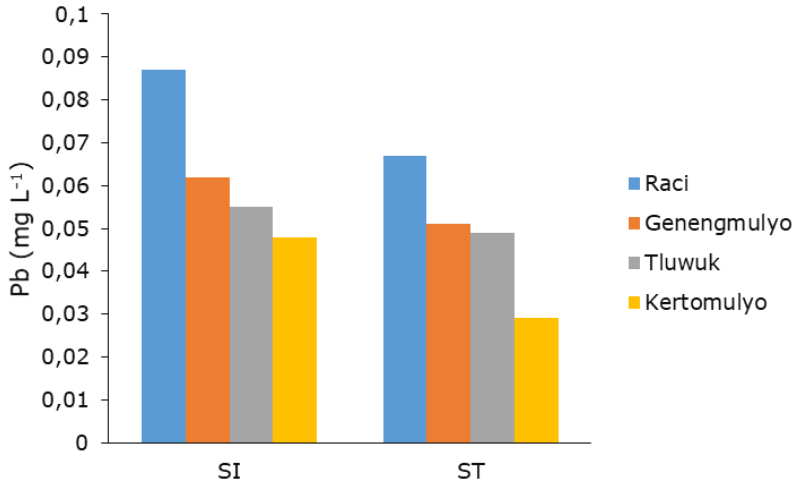


Figure 2. Measurement results of lead (Pb) content in salt crystallization table (SI-integrated system, ST-traditional system).

Pb is one of the toxic heavy metals that can accumulate into organisms and abiotic components of the food chain, including salt. The measurement results of the Pb content ranged from 0.025 to 0.087 mg $L^{-1}$ in the integrated saltwork land and from 0.048 to 0.079 mg $L^{-1}$ in the traditional saltwork land. The Pb content is still in accordance with the Environmental Decree number 51 of 2004, concerning the Seawater quality standards (Ministry of Environment 2004).

***Temperature***. Temperatures tend to increase during the day and to decrease in the afternoon. The temperature range of the integrated salt crystallization table was higher than in the traditional salt crystallization table. This was due to the presence of a geo-isolator/geomembrane layer on the crystallization table in the integrated saltwork area. The range of temperature measurement results is presented in Figure 3. The results of the temperature measurements of the crystallization table I increased during the day, by around 1.33°C, both at the integrated and traditional saltwork lands. In the evening, the temperature decreased by an average of 1.47°C at the integrated saltwork land and by 1.62°C at the traditional saltwork land.

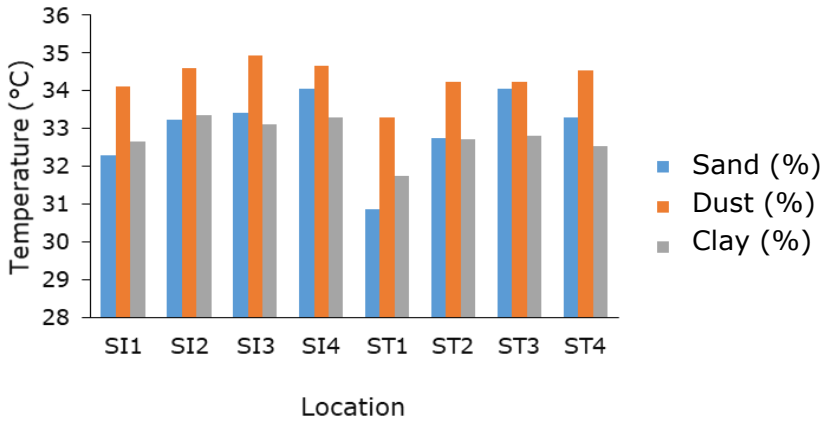


Figure 3. Temperature conditions at the integrated and traditional saltwork systems in Pati Regency, Central Java, Indonesia (SI-Integrated system, ST-Traditional system, 1-Raci Village, Batangan Subdistrict, 2-Genengmulyo Village, Juwana Subdistrict, 3-Tluwuk Village, Wedarijaksa Subdistrict, 4-Kertomulyo Village, Trangkil Subdistrict.

***The relationship of physicochemical and biological parameters on the saltwork systems***. The PCA analysis was performed to determine the relationship between physicochemical and biological parameters in the saltwork system lands (Figure 4). The cumulative percent variance of the F1 and F2 eigenvalues was of 56.93%. The results of the loading factor showed that the integrated system had an abundance of gastropod and plankton species. Factor F1 showed that the sand substrate had a positive relationship with the presence of *S. riquetii*. *T. palustris*, *T. terebra*, in which the smaller percentage of sand resulted in a higher abundance of these gastropods. Abundance is inversely proportional to the temperature. The F2 factor described that in conditions of dusty substrate and higher Pb content, a high abundance of *S. ventricosa* and zooplankton was found. The higher dust substrate alone resulted in a higher abundance of phytoplankton. A higher specific gravity of the water salt resulted in a lower abundance of *S. ventricosa*.

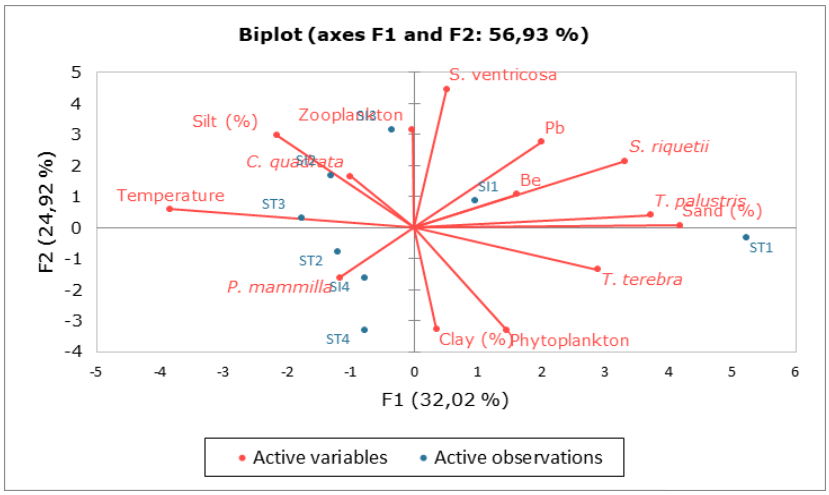


Figure 4. The relationship between physicochemical and biological parameters in the saltwork system lands, Pati Regency, Central Java.

The water temperature and salinity have an influence on the dynamics of the plankton community (Gu et al 2021). The saltwork area is related to the mangrove ecosystem. The water that flows to the saltwork area also passes through the mangrove ecosystem so that it has an effect. Mangrove ecosystems can supply food in the saltwork areas. Mangrove ecosystems are known as sources of food for gastropods (Ariyanto 2019) and of bioactive compounds (Ariyanto et al 2019; Ningsih et al 2020), in particular of antimicrobial compounds (Pringgenies et al 2021). In addition, in the mangrove

ecosystem the decomposition rate and productivity support the availability of food sources for gastropods.

The health of the plankton community can be assessed using biomarkers. The availability of food can affect the contribution of plankton, environmental stress (Ji et al 2021) and the influence of microplastics (Rodrigues et al 2021). Predation processes release ammonium and other nutrients which further stimulate growth (Zhang et al 2018). Pb also has a negative correlation with plankton. A negative correlation was found between plankton biomass and Pb concentration (Gagneten & Paggi 2009). Water temperature is a key factor affecting the plankton dynamics in shallow productive coastal waters (Trombetta et al 2019), changing the community structures (Rasconi et al 2015) and subsequently the temperature conditions affect the food web processes and existing ecosystem services.

**Conclusions**. The integrated saltwork system is better, compared to the traditional system in terms of physicochemical and biological parameters. This finding can be applied to improve the salt quality and the environmental stability from an ecological perspective, supported by various physicochemical and biological factors. Among the physicochemical factors, the temperature and salt specific gravity in the saltwork system have an effect on the salt quality. From an ecological perspective, the integrated saltwork system better supports the diversity of plankton and gastropod species compared to the traditional system.

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**Conflict of interest**. The authors declare no conflict of interest.

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