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NOTE

Temperature and salinity variation in oscular tubes of the branching sponge *Haliclona* sp. inhabiting a tidal pool influenced by fresh groundwater discharge in Taiwan

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ABSTRACT: This study recorded temperature and salinity in oscular tubes of the branching sponge (*Haliclona* sp.) living in an intertidal coral reef with fresh groundwater inflow on Green Island, Taiwan. During the ebb tide period, seawater temperature and salinity around the sponges ranged from 30.6 to 34.1°C and 17 to 27‰, respectively. The temperature and salinity within sponge oscular tubes were 30.8 - 34.5°C and 23 - 27‰, respectively. The oscular openings usually had higher salinity than ambient waters near the fresh groundwater inflow. Some of the largest differences in salinity between the sponge oscular tube and ambient seawater were in the range of 6 - 8‰. The sponges regularly experienced wide fluctuations in salinity (4 - 28‰) and temperature (23.2 - 34.8°C) for at least 3 hours during ebb tide periods. Whether the ostia play a role in actively maintaining the internal salinity of the branching *Haliclona* sponges needs further investigation.

KEY WORDS: Fresh groundwater, oscular tube, sponge, salinity, temperature.

INTRODUCTION

Coral reef organisms in coastal areas usually face high chemical, physical, and hydrological variability caused by typhoons, heavy rain, coastal runoff, fresh groundwater, or wastewater. Freshwater input may induce changes in aquatic vegetation and benthic communities (Santos *et al*., 2011). For example, macroalgal and seagrass community structure studies show decreased abundance and diversity in areas with submarine groundwater discharge (La Valle *et al*., 2021; Sims *et al*., 2020). In addition, algal turf and zoanthids are more likely to grow in such areas (La Valle *et al*., 2021). As a component of coral reefs, sponges face such stresses, especially in the intertidal zone, which may result in unhealthy symptoms or even death (Fell *et al*., 1989). Although such daily and seasonal fluctuations in temperature and salinity are natural phenomena in coastal environments, few field studies target sponges.

At an intertidal coral reef on Green Island off the southeast coast of Taiwan, a fresh groundwater inflow area was observed in the vicinity of a sponge population during ebb tide (Fig. 1). The water around the sponge oscules appeared to be blurred (Fig. 2), due to mixing of seawater with different temperature, and/ or salinity. We were interested in determining whether differences in temperature and/ or salinity were the cause of this phenomenon. Therefore, we conducted in situ measurements of temperature and salinity in oscular tubes of the sponge *Haliclona* sp. and ambient seawater to investigate this phenomenon.

MATERALS AND METHODS

Fieldwork was conducted at a coral reef intertidal area near the inflow of fresh groundwater during a calm ebb tide on June 15, 2010, at Guiwan, Green Island, Taiwan (22°38′45.12″N, 121°28′45.65″E) (Fig. 1). The sponge *Haliclona* sp. is a black soft, stalked, tubular species commonly seen in tidal pools along the east coast of Taiwan. The size of those sponge individuals ranged from 5 to 16 cm.

We determined the temperature and salinity within oscular tubes in six sponge individuals from Zone N and Zone F, which were near (N) and far (F) from the fresh groundwater inflow, respectively (Fig. 1). For each sponge individual, we took about 20 minutes to make 12 temperature and salinity measurements from the opening to the bottom of the longest oscular tube. In addition, temperature and salinity profiles of ambient seawater outside the oscules were measured every 2 cm from the water surface to reef substrata where *Haliclona* sponges grew.

For data collection, an electronic temperature probe (Suntex, TS-100) was applied to the ambient seawater approximately 1 - 2 cm away from the sponge or in the sponge oscular-targeted site. Salinity was measured with a refractometer (Atago S/Mill-E) after taking a drop of seawater from the ambient environment as well as that within the sponge's oscular tube using a dropper. The researcher stood downstream of the sample to minimize disturbance to the sponges during the measurements. Afterward, the data were analyzed and compared among sponge individuals, using one-way analysis of variance (ANOVA) and the post hoc Tukey's multiple-comparisons test.

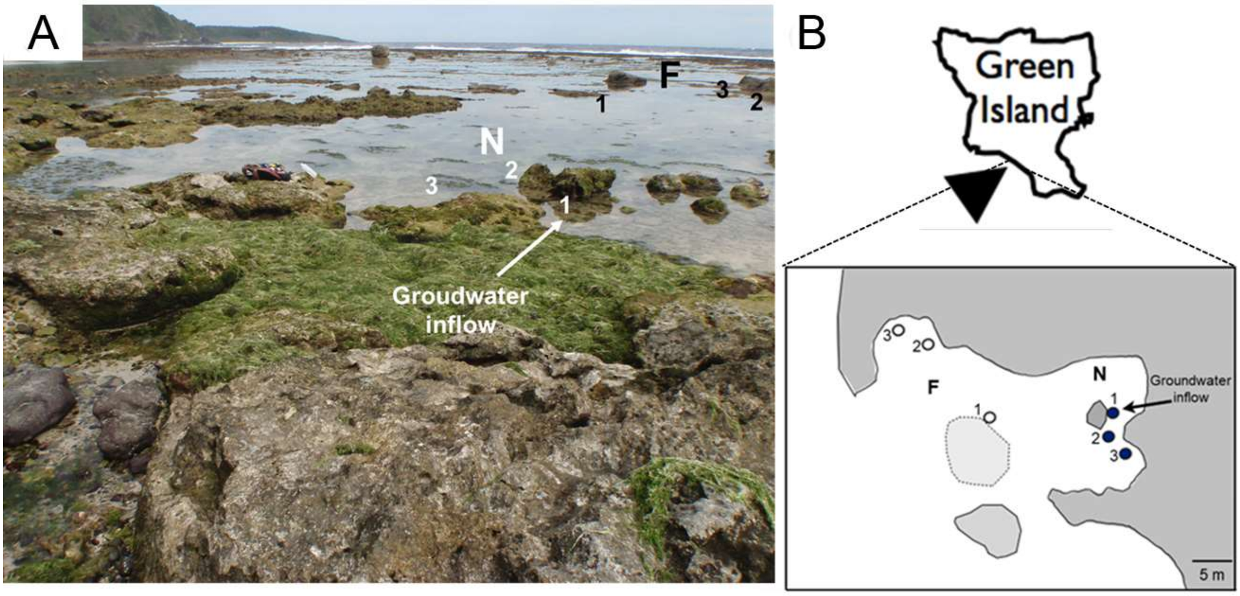

Fig. 1. Sampling site at Guiwan, Green Island. **A.** The environments and the relative distance of sponges in the tidal pool. **B.** The plan view of the tidal pool.

Fig. 2. The branching ***Haliclona*** sponges distributed near the fresh groundwater inflow at Guiwan. The blurring is on the upper part of the photo.

RESULTS AND DISCUSSION

The six *Haliclona* sponges grew in a shallow intertidal pool (< 50 cm deep during ebb tides). Their oscular openings were 3.5–15.0 cm below the water surface at low tide (Table 1 and Fig. 3). In the vicinity of the fresh groundwater inflow, temperature and salinity profiles of the seawater showed vertical stratification (Figs. 1 & 3). We compared the differences in temperature and salinity of seawater between the ambient environment and that within the oscular tube at the same depth to elucidate the sponges' responses (Table 1). In Zone F, the temperature and salinity of seawater within sponge oscular tubes and from ambient environment were 30.8–34.1 vs. 30.6–34.1°C and 24–27 vs. 25–26‰, respectively. In zone N, a more significant difference was recorded between oscular tubes and ambient seawater in temperature and salinity, i.e., 33.3–34.5 vs. 32.5–33.9°C and 23–27 vs. 17–27‰, respectively. Sponge N3 had the most extreme difference in salinity between the oscular tube and ambient seawater, i.e., 23–25 vs. 17–24‰. Seawater at higher temperature and salinity was observed in the oscules of sponge N1 compared to N3, F2, and F3, respectively ($p < 0.05$) (Table 1). However, the difference did not correlate with the distance of the sponge individual from the source of fresh groundwater inflow.

Sponges can control their water flow and pumping rate by wholly or partially contracting and expanding their oscula and ostia in response to various environmental stresses (Reiswig 1971; Singh *et al*., 2022). In laboratory experiments, the boring sponge *Cliona celata* was well adapted to salinity stress and showed no pigment loss when kept in 22, 32, and 42‰ (Knight and Fell 1987). In another study, the pumping activity of *C. celata* continued at 20‰ but reduced at 15‰ and became inactive at 10‰ (Hartman 1958; Aantos *et al*., 2011). Lopez-Legentil *et al*., (2008) found *Xestospongia muta* was unaffected by salinity in 35.5–41.0‰. In the euryhaline sponge *Microciona prolifera*, survivors revealed reversible tissue regression if salinity was gradually decreased (Duckworth *et al*., 2012). However, when salinity dropped directly from 30 to 10‰, the sponge was severely damaged and eventually died. The regulation ability of sponges varies depending on not only environmental factors but also the physiological conditions of the investigated species.

Singh *et al*., (2022) investigated the tolerance of sponge *Cinachyrella cf. cavernosa* to intertidal environmental stress, which was transplanted from a mid- to the high-intertidal area for 15 days on a rocky shore in

Table 1. Temperature and salinity of ambient seawater and seawater in the oscular tubes of *Haliclona* sponges. Multiple comparisons with different letters are significantly different (p < 0.05).

Sponge	Distance of oscules below the water surface (cm)	Length of the oscular tube (cm)	Environmental temperature (ºC)	Temperature (ºC) within the oscular tube	Mean temperature (ºC) within the oscular tube (Mean±SD)	Environmental salinity (‰)	Salinity (‰) within the oscular tube	Mean salinity (‰) within the oscular tube (Mean±SD)
N1	9.0	7.0	33.3–33.8	34.5	34.5 ± 0.1 a,b	23–27	26–27	26.8 ± 0.6 a,b
N2	7.5	6.0	33.5–33.9	33.6–33.9	33.7 ± 0.1 b,c	23–25	23–26	25.4 ± 0.9 b,c
N3	3.5	5.5	32.5–33.9	33.3–33.6	33.3 ± 0.3 c,d	17–24	23–25	23.9 ± 1.2 c
F1	8.0	10.0	33.9–34.1	33.8–34.1	33.9 ± 0.2 b,c	26	26–27	26.7 ± 0.5 a,b
F2	15.0	13.0	31.1–31.3	31.1–31.3	31.2 ± 0.1 d	25	25–25	25.1 ± 0.3 c
F3	7.0	16.0	30.6–30.8	30.8–31.0	30.8 ± 0.1 d	25	24–26	24.8 ± 0.6 c

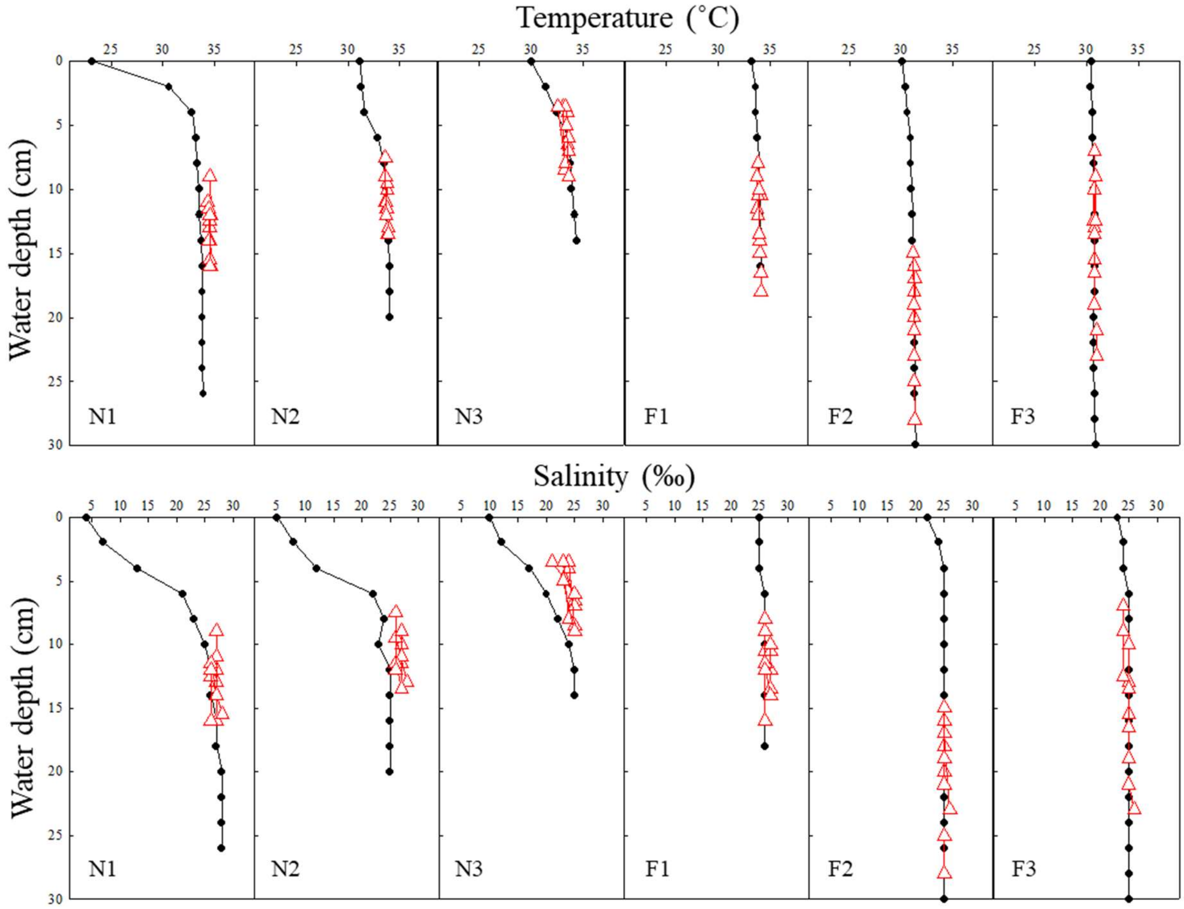

Fig. 3. Temperature and salinity profiles of the branching *Haliclona* sponges and ambient seawater at Guiwan. Sponges were close to (N1-N3) or away from (F1-F3) fresh groundwater inflow. ●: seawater measurements, △: sponge measurements.

Anjuna, India. Transplanted sponges in high-intertidal zone experienced more intensive temperature and salinity variations than those in the mid-intertidal zone, i.e., 29.9–36.2°C and 35.0–46.7‰ vs. 27.0–33.0°C and 35.5‰, respectively. The oscular openings per sponge decreased from 3 to 2, then 0 on days 0, 5, and 11, respectively; most transplanted sponges died due to tissue necrosis at the end of the experiment. The result indicated that the environmental stress experienced by the sponge *C. cf. cavernosa* in the high-intertidal area is beyond its adaptation ability.

In this study, due to the inflow of fresh groundwater, the tidal pool regularly experienced wide fluctuation in salinity (4–28‰) and temperature (23.2–34.8°C) for 6 - 8 hours during spring tides or 3–4 hours during neap tides at Guiwan. Neither bleaching nor mortality was observed for the green alga *Ulva* sp., brown alga *Padina* sp., branching *Haliclona* sponges, hard coral *Dipsastraea* sp., sea anemone *Stichodactyla gigantean*, sea star *Linckia laevigata*, and sea cucumber *Holothuria atra* in such environments (personal observation). The blurring phenomenon resulted from the pumping disturbance of sponges to the stratified seawater with different temperatures and salinities. It is suggested that salinity played a more important role than temperature based on their differential gradients. Whether the contraction of ostia is involved in controlling the internal salinity of the *Haliclona* sponges needs further examination.

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