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Impact of the on-site fish workshop in gaining children's understanding and support for coastal zone management: leverage points and human-nature connection perspectives

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Public understanding and support are essential for managing coastal zones because these are social-ecological systems (SES) in which the public plays a crucial role. As disconnection from nature may be a root cause of the unsustainability of SES, reconnecting people to nature is a promising avenue for improving their understanding and support. Although environmental education that involves exposure to nature has been considered influential in reconnecting people with nature, empirical research is lacking. Therefore, this study aimed to assess the impact of an on-site fish workshop on Japanese elementary and junior high school student's knowledge, attitudes, intentions, and behaviors through the notion of human-nature connection (HNC) and leverage points. A 2×2 difference-in-differences design was employed in which the workshop's impact was assessed by comparing the treatment and control groups before and after the workshop. We collected 4,054 responses, with 1,243 (pre-) and 1,088 (post-) students in the treatment group and 857 (pre-) and 866 (post-) in the control group. The preliminary findings indicate that the workshop had diverse impacts, from shallow (parameters) to deep leverage points (Information flows, Rules, Goals, and Paradigms), including HNC, support for ongoing management measures, and pro-SES attitudes and intentions. Their diverse impacts in the same direction (i.e., improvements), as found in our study, are critical because leverage points should be aligned for systemic sustainability transformation. However, changes to leverage points measured in the average treatment effect on the treated (ATET) varied from limited to extensive. Future research directions are discussed based on the preliminary findings.

KEYWORDS

coastal zone management, difference-in-differences, environmental education, human-nature connection, Japan, leverage points, social-ecological system, ocean education

1 Introduction

The sustainable management of social-ecological systems (SES) has become increasingly important as it provides a robust analytical framework for understanding two deeply intertwined systems and addressing sustainability problems (Fischer et al., 2015). Ecosystem management to conserve ecosystems and ignore the consequences and influence of social systems can lead to an undesirable SES state (Preiser et al., 2021). Therefore, changes in SES should increase the associated social welfare without compromising ecosystem integrity (Uehara et al., 2016).

Owing to the inherent nature of people playing critical roles in SES, it is important to gain public understanding and support for management (Uehara and Hidaka, 2023). Uehara and Hidaka (2023) proposed four reasons for gaining public support for management: accountability, aligned goals, backing, and involvement. First, accountability is integral to legitimate management (Boesch, 2019; DeAngelis et al., 2020). Second, the management must pursue goals aligned with public desires (De Wit et al., 2020; Uehara et al., 2022). Third, public backing enables smooth management implementation and faces challenges from various stakeholders (Boesch et al., 2001; De Wit et al., 2020). Fourth, public support may lead to active stakeholder involvement in management, such as conservation activities (Greening et al., 2014; Boesch, 2019; Uehara et al., 2022).

Strengthening the human-nature connection (HNC) is promising for improving public understanding and support for SES management, including coastal SES (Celliers et al., 2023; Kelly et al., 2021). Society's disconnection from nature is a root cause of SES's unsustainability (Abson et al., 2017; Ives et al., 2018; Nisbet et al., 2009; Uehara et al., 2019). HNC has five dimensions: material, experiential, cognitive, emotional, and philosophical (Riechers et al., 2022). HNC is positively associated with attitudes and behaviors toward the environment (Ives et al., 2018). Therefore, reconnection is a promising avenue for promoting people's pro-sustainability attitudes and behaviors (Zylstra et al., 2014; Restall and Conrad, 2015; Sandifer et al., 2015; Ives et al., 2018). However, empirical evidence for reconnecting people to nature for sustainable system transformation is scarce (Ives et al., 2018).

Therefore, this study aims to empirically investigate the impact of environmental education on children's understanding of and support for SES management by reconnecting them to nature. This case study involved an on-site fish workshop for elementary and junior high school students in Hyogo Prefecture, Japan. Although the younger generation can be a critical agent of sustainable change, their disconnection from nature is ongoing (Pergams and Zaradic, 2008; Soga and Gaston, 2016; van de Wetering et al., 2022). Urbanization is a major driver of disconnection from nature (Kareiva, 2008; Miller, 2005). A meta-analysis revealed that environmental education can improve children's environmental knowledge, attitudes, intentions, and behaviors (van de Wetering et al., 2022). Furthermore, environmental education, which provides children with experience and knowledge, is considered to reconnect them to nature and improve their environmental education outcomes, which could deepen their understanding of and strengthen support for SES management (Chawla, 2020; Price et al., 2022). However, empirical research on the impact of environmental education on connectedness is lacking (Whitburn et al., 2023).

We employed a leverage points perspective as a theoretical framework to interpret the impact on students regarding its potential contribution to the sustainability transformation of SES (Cunningham, 2021; Riechers et al., 2021a) and adopted the difference-indifferences (DD) design to generate and analyze the data for measuring it (Angrist and Pischke, 2008). To our knowledge, using a leverage point perspective and DD design to evaluate the impact of environmental education is novel, contributing to the diversity of research designs and assessment methods, a deeper understanding of children's behavioral change processes, and a more rigorous knowledge base for educators and policymakers (van de Wetering et al., 2022). Leverage points are places in a system to intervene to make a significant shift in the system's behavior with a small change to these points (Meadows, 2008). Places can be any system element, including people's minds and behaviors, relationships, physical structures, paradigms, and rules. For example, raising taxes can change economic system dynamics (e.g., GDP) by influencing consumer behavior. While leverages have been widely studied in systems analysis to identify places to make changes to the system (Sterman, 2000; Nguyen and Bosch, 2013; Roxas et al., 2019), sustainability science has shed light on this perspective as a promising way to identify places to intervene to achieve the sustainability transformation of SES (Abson et al., 2017; Linnér and Wibeck, 2021). HNC is one of the key realms of leverage in the context of SES (Abson et al., 2017; Mattijssen et al., 2020; Riechers et al., 2021b). Abson et al. (2017) categorized the 12 leverage points contrived by Meadows (2008) into four system characteristics (Table 1). It systemically and comprehensively embraces the elements for sustainability transformation from parameters to intent (Fischer and Riechers, 2019). The degree of effectiveness differed from that of the shallowest group (12. parameters) to the deepest (1. Power to transcend paradigms). While deeper leverage can have a greater impact than shallower leverage, changing may be more challenging. It has been widely used in sustainability science (Fischer and Riechers, 2019; Dorninger et al., 2020; Bryant and Thomson, 2021; Fischer et al., 2022). For example, sharing the desirable state of SES among people is challenging, it could have a significant impact on people's behavior and contribution to the sustainability transformation. Leverages help us identify potentially effective points of a system to intervene and induce a desirable change in the system's behavior. Therefore, we adopted the leverage points perspective by hypothesizing that it can identify and interpret how changes in students induced by environmental education contribute to the sustainability transformation of SES. DD is a quasi-experimental method for assessing the causal effects of a program by comparing before-and-after changes and removing selection bias and unobservable differences by comparing treatment and control groups (Angrist and Pischke, 2008). A design using one but not both may lead to counterfeit estimates of causal effects (Gertler et al., 2016).

TABLE 1 Twelve leverage points (Meadows, 2008) and corresponding four system characteristics (Abson et al., 2017).

	Leverage point (in increasing order of effectiveness)	System characteristic
Shallow leverage points	12. Numbers 11. Buffers 10. Stock-and-Flow Structures	Parameters: The relatively mechanistic characteristics typically targeted by policymakers
	9. Delays 8. Balancing Feedback Loops 7: Reinforcing Feedback Loops	Feedbacks: The interactions between elements within a system of interest that drive internal dynamics
Deep leverage points	6. Information Flows 5. Rules 4. Self-Organization	Design: The social structures and institutions that manage feedbacks and parameters
	3. Goals 2. Paradigms 1. Transcending Paradigms	Intent: The underpinning values, goals, and world views of actors that shape the emergent direction in which a system is oriented

2 Materials and methods

The on-site fish workshops were organized by the Hyogo Prefecture Federation of Fishermen's Cooperative Associations. From July to December 2023, lecturers were sent to 40 elementary and junior high schools with 2,126 students in total (aged 10–14 years). The students learned how to fillet and prepare whole fish and about the current state of the sea in Hyogo Prefecture. For example, they explained that the Seto Inland Sea (SIS), adjacent to Hyogo Prefecture, experiences oligotrophication, causing a decline in fish catch and bleaching of cultured nori (*Pyropia yezoensis*). Therefore, this area's current coastal nutrient management plan intends to increase the nutrient supply (Uehara and Hidaka, 2023).

We prepared two online surveys: one for the control group before and after the workshop, and the treatment group before the workshop, and one for the treatment group after the workshop. Excluding additional questions about the workshop in the latter (see Supplementary Material (SM) for the surveys), the two surveys were identical. The questions were developed based on literature and non-participant observations in a workshop held at an elementary school on July 20, 2023. The teacher who supervised the workshop checked the surveys and made necessary changes accordingly (see Supplementary Material for the surveys). The survey comprised three parts: student characteristics, changes in their knowledge, attitudes, intentions, behaviors, and opinions about the workshop. The third was limited to the post-workshop treatment group. The changes were related to understanding and support for coastal zone management (CZM) and were considered potential leverage points for three system characteristics: parameters, design, and intent. It is critical to assess multiple leverage points because their alignment is integral to transforming a system in the correct direction (Fischer et al., 2022). The parameters included the frequency of seafood consumption and seafood preferences. The design included knowledge of the sea, the desirable color of the sea, fish preparation cooking, and the level of support for current coastal management measures.

Five nutrient supply measures were evaluated using a Likert scale (Uehara and Hidaka, 2023). The intent included a sense of connectedness to the SIS and the city, three types of sea values (instrumental, intrinsic, and relational), and being pro-SES. For a sense of connectedness, graphical representations of the relationships were drawn from the inclusion of nature in self (INS) scale, a psychological human-nature connection scale, and a contextual human-nature connection scale (Giusti, 2019). Graphical representations are said to be easy for children to understand (Giusti, 2019). Relational, instrumental, and intrinsic values are vital deep leverage points (Mattijssen et al., 2020; Riechers et al., 2021b; Himes et al., 2024). Items for measuring these values using a Likert scale were adopted from Uehara et al. (2022), who studied the same coastal zones. Items for measuring pro-SES using a Likert scale tailored for this context were also adopted from Uehara et al. (2022) because they were aligned with the CZM of this area.

Survey participants in the treatment and control groups were students aged 9–14 years, recruited from schools that hosted the workshop during the second semester in 2023; 32 of the 40 schools that participated in the workshop in 2023 were covered. Those in the treatment groups participated in the workshop, and those in the control group did not. Each school assigned both treatment and control groups by selecting specific classes. For the treatment group, the school designated a class to participate in the workshop, ensuring that all students in the selected class attended, regardless of their individual interests. Similarly, the school selected a control group class with students of the same or similar ages (e.g., within one year younger or older) as those in the treatment group. The minimum age was chosen because nine is considered old enough to measure environmental attitudes and behaviors (Otto et al., 2019). Based on the consultation with the school's principal and teacher presiding over the workshop, where we conducted non-participant observation for designing the survey, we obtained informed consent from the principals responsible for the workshop on behalf of the student's legal guardians. Furthermore, students were informed that they could decide whether to answer the questionnaire. No data that could identify individuals were collected. Online surveys were conducted using SurveyMonkey, as all students had access to the Internet at school. The surveys were conducted under the teacher's supervision and administered twice to the treatment group before and after the workshop. We requested schools to administer the surveys to the control group at the same time as the treatment group. The survey questions were the same across groups except for the post-workshop survey in the treatment group who answered questions about the workshop experience (see the Supplementary Material for details). The interval between the pre- and post-implementation questionnaires was set to approximately one month following existing studies (Giusti, 2019; Iwasaki, 2022; Chanvin et al., 2023). A link to the first survey and instructions were e-mailed to each school two weeks before the workshop, and the responses were submitted before the workshop. A follow-up survey was conducted 3 weeks after the workshop using the same procedure. Although the deadline was within two weeks after the

questionnaires were sent, it was extended for some due to long school vacations or cancellation of classes. As a result, the average interval between pre- and post-implementation questionnaires was 40.8 days, with an average of 6.4 days (standard deviation 4.2) before the workshop for the pre-implementation questionnaire and 34.4 days (standard deviation 10.9) after the workshop for the post-implementation questionnaire. There were 4,054 valid responses, with 1,243 (pre) and 1,088 (post) in the treatment group and 857 (pre) and 866 (post) in the control group.

The collected data, excluding open-ended responses, were analyzed by applying a 2×2 DD design (Cunningham, 2021); this design assesses the workshop's causal effects on the treatment group by comparing changes in leverage points (e.g., Knowledge of the SIS) between two groups (i.e., the treatment and control groups) across two time periods (i.e., the pre-and post-workshop). Figure 1 is a graphical presentation of the 2×2 DD design. The outcome in Figure 1 is leverage points in our study. The average treatment effect on the treatment group (ATET = γ in Figure 1) captures the causal effects by comparing the observed outcome trend of leverage points in the treatment group (α in Figure 1) and the unobserved counterfactual outcome trend of them for the treatment group that is derived from the observed outcome trend in the control group (i.e., β in Figure 1). ATET was estimated by fitting a linear model using STATA BE 18 (Stata. com). School year and sex were included in the model to consider individual characteristics in computing ATET. Free-answer questions were analyzed using a co-occurrence network with KH coder version 3.00 (https://khcoder.net/), which visualizes how terms are used together and elucidates the topics mentioned in the text.

3 Results

Table 2 shows the workshop's impact on the participants' knowledge, attitudes, intentions, and behaviors. The leverage points perspective organizes them. The Cronbach's alpha for instrumental, intrinsic, and relational values (0.846, 0.857, and 0.908, respectively) indicated reliability, although 0.908 was slightly higher than the recommended 0.90 (Tavakol and Dennick, 2011). While most changes were statistically significant, excluding "support for management 5: Conserving, restoring, and creating shallow coastal areas" and "relationship with the city," the degree of change measured by ATET varied. For example, knowledge of filleting fish improved by 1.732 points on a scale of 1 to 5, and preferences for fish dishes improved by only 0.043 points on a scale of 1 to 5.

Figures 2A and B show the co-occurrence networks of the "rich SIS" in the treatment group before and after the workshop. While there was no distinctive change in the association of the words "clean sea with many delicious fish" (Subgraph 03 in Figure 2A, Subgraph 03 in Figure 2B), expressions that characterize the rich SIS, such as plankton, appropriate, and balance, appeared (Subgraph 01 in Figure 2B). Although the color of the sea was described as blue, which is not a correct understanding, both before and after the workshop, after the workshop, it was also described as green, which is the correct understanding (Subgraph 06 in Figure 2B). For example, one respondent said, "The water is a little green, and the fish are lively." Thus, it can be assumed that the workshop deepened their understanding of rich SIS.

Finally, 92.19% of the participants talked to their families about the workshop. They mostly talked about how to fillet a fish (81.34%), but some also talked about the current state of the SIS (5.88%) and the rich sea (5.79%).

4 Discussion

This study aimed to assess the impact of an on-site fish workshop on children from the perspectives of reconnecting people to nature as a root cause of unsustainability and the leverage points to identify elements that effectively improve their understanding and support for SES management toward sustainability transformation. The ATET estimated using the 2×2 DD design revealed that overall, the workshop made statistically

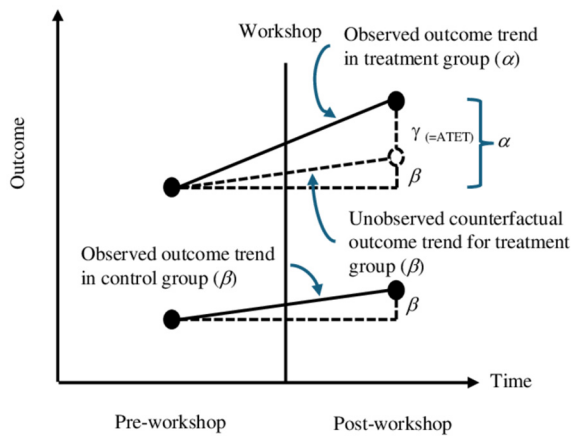

FIGURE 1
Graphical presentation of 2×2 DD design.

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TABLE 2 Summary of changes to leverage points before and after the workshop.

System characteristic	Leverage point type	Leverage point	Scale	Pre-workshop mean in treatment	Post-workshop mean in treatment	ATET	*p*-value	sig.
Shallow leverage points								
Parameters	12. Numbers	Preferences for fish dishes	1. Strongly dislike, …, 5. Strongly like	3.718	3.736	0.043	0.005	**
		Ate seafood within the past week	% of yes	0.153	0.199	0.054	0.002	**
Deep leverage points								
Design	6. Information flows	Knowledge of filleting a fish	1. I have never heard of it, …, 5. I know it well	2.278	3.996	1.732	0.001	**
		Knowledge of the SIS	1. I have never heard of it, …, 5. I know it well	1.672	2.604	0.874	0.001	**
		Knowledge of the desirable sea color	% of correct answer	0.184	0.573	0.391	<0.001	***
	5. Rules	Support for management 1: Supplying nutrients from factories and sewers	1. Completely unsupportive, …, 6. Strongly supportive	4.063	4.175	0.147	0.002	**
		Support for management 2: Fertilizing the sea	1. Completely unsupportive, …, 6. Strongly supportive	4.105	4.158	0.123	0.010	*
		Support for management 3: Plowing the seabed	1. Completely unsupportive, …, 6. Strongly supportive	4.354	4.406	0.110	0.001	**
		Support for management 4: Discharging nutrient-mixed pond water	1. Completely unsupportive, …, 6. Strongly supportive	3.973	4.096	0.078	0.001	**
		Support for management 5: Conserving, restoring, and creating shallow coastal areas	1. Completely unsupportive, …, 6. Strongly supportive	4.465	4.413	0.018	0.060	
Intent	3. Goals	pro-SES 1: The SIS should aim to become a "rich sea" with a balance between water quality (transparency) and fish catch.	1. Strongly disagree, …, 5. Strongly agree	4.114	4.016	0.019	0.048	*
		pro-SES 2: I would like to participate in sea-related events held in the coastal zone of the SIS and visit the aquariums and beaches.	1. Strongly disagree, …, 5. Strongly agree	3.643	3.628	0.032	0.044	*
		pro-SES 3: If I eat seafood, I would like to eat seafood from the SIS.	1. Strongly disagree, …, 5. Strongly agree	3.529	3.639	0.157	0.005	**
		pro-SES 4: I try to dispose of my plastic waste correctly.	1. Strongly disagree, …, 5. Strongly agree	4.234	4.183	0.061	0.009	**
		pro-SES 5: I want to contribute to the preservation activities of the SIS.	1. Strongly disagree, …, 5. Strongly agree	3.635	3.710	0.152	0.014	*

(Continued)

TABLE 2 Continued

System characteristic	Leverage point type	Leverage point	Scale	Pre-workshop mean in treatment	Post-workshop mean in treatment	ATET	*p*-value	sig.
Deep leverage points								
		pro-SES 6: I want to contribute to cleanup activities in the SIS.	1. Strongly disagree, …, 5. Strongly agree	3.557	3.638	0.184	0.012	*
	2. Paradigms	Overall support for a desirable state of the sea	1. Strongly disagree, …, 5. Strongly agree	3.672	3.732	0.231	0.005	**
		Relationship with the SIS (HNC)	1. Farthest relationship, …, 7. Closest relationship	2.097	2.435	0.263	0.007	**
		Relationship with the city	1. Farthest relationship, …, 7. Closest relationship	3.458	3.370	-0.041	0.056	
		Instrumental values	1. Strongly disagree, …, 5. Strongly agree	3.909	3.955	0.090	<0.001	***
		Intrinsic values	1. Strongly disagree, …, 5. Strongly agree	4.327	4.205	0.036	0.011	*
		Relational values	1. Strongly disagree, …, 5. Strongly agree	3.793	3.798	0.065	0.013	*

See Supplementary Material for the details, including mean values in the control groups.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

significant improvements in the leverage points (Table 2), including the HNC ("Relationship with the SIS"). Their diverse impacts in the same direction (i.e., improvements in our context) are critical because leverage points should be aligned for systemic sustainability transformation (Fischer et al., 2022). Furthermore, since leverage points interact with each other (Fischer et al., 2022), improvement in leverage points directly related to the HNC may influence other leverage points, such as those related to the understanding and support for SES management.

The impact is diverse, from shallow, which is relatively easy to change but has limited influence, to deep leverage points, which are relatively difficult to change but potentially cause transformational change (Abson et al., 2017). They contribute to their understanding (e.g., enhanced knowledge), indirect support (e.g., greater appreciation of instrumental and relational values), and direct support for CZM (e.g., enhanced support for ongoing measures and agreement with pro-SES). This finding is reasonable because their disconnectedness from the sea, filleting an entire fish, and cooking a fish dish were vivid stimulus nature exposures that could enhance connectedness (Chawla, 2020). The mean HNC value for the treatment group was 2.097 on a scale of 1–7, whereas the relationship with the city was 3.458. A recent nationwide survey also reported the disconnectedness from nature, that 65.4% of teenage respondents visited the sea equal to or less than once a year, and 42.5% did not have an attachment to the sea (The Nippon Foundation, 2017).

However, it should be noted that the degree of impact measured in ATET varied, indicating the heterogeneous effectiveness of the workshop on the leverage points, from limited to extensive. For example, among "2. Paradigms," the deepest leverage points in our study, the HNC ("relationship with the SIS") and "Overall support for a desirable state of the sea" vastly improved (ATET = 0.263 on a scale of 1 to 7, and 0.231 on a scale of 1 to 5) relative to instrumental, intrinsic, and relational values (ATET = 0.090, 0.036, and 0.065 respectively on a scale of 1 to 5). The impact of environmental education on HNC has been well supported in the literature (Chawla, 2020), although this is not always the case (Whitburn et al., 2023). The desirable state of the sea seemed to be directly related to the workshop's content. As values transcend specific situations (Schwartz, 1994), it is reasonable that the workshop's impact on values was relatively limited. As for "3. Goals," and degree of improvement of pro-SES items also varied. Pro-SES scores of 3, 5, and 6 were relatively high (ATET = 0.157, 0.152, and 0.184 on a scale of 1 to 5, respectively). They were more directly related to fish than the other items. As for "5. Rules," while the support for the first three management measures improved ("Supplying nutrients from factories and sewers," "Fertilizing the sea," and "Plowing the seabed"), the limited improvement regarding the fourth measure ("Discharging nutrient mixed pond water") and no significant improvement to the fifth one ("Conserving, restoring, and creating shallow coastal areas"). As the participants were given no explanation of each measure and provided only their measure names with images (see Supplementary Material), it is plausible that they did not know the effectiveness of each measure. The changes were ascribed to the ease of comprehending the measures; this implies that further explanations may have different effects. All "6. Information flow" changed significantly. As the values before the workshop showed, participants' knowledge left room for improvement. Furthermore, they improved significantly because they had experienced filleting a fish and received explanations about the current state of the SIS and its desirable color directly related to the questions. Co-occurrence networks showed that their understanding of the rich sea deepened.

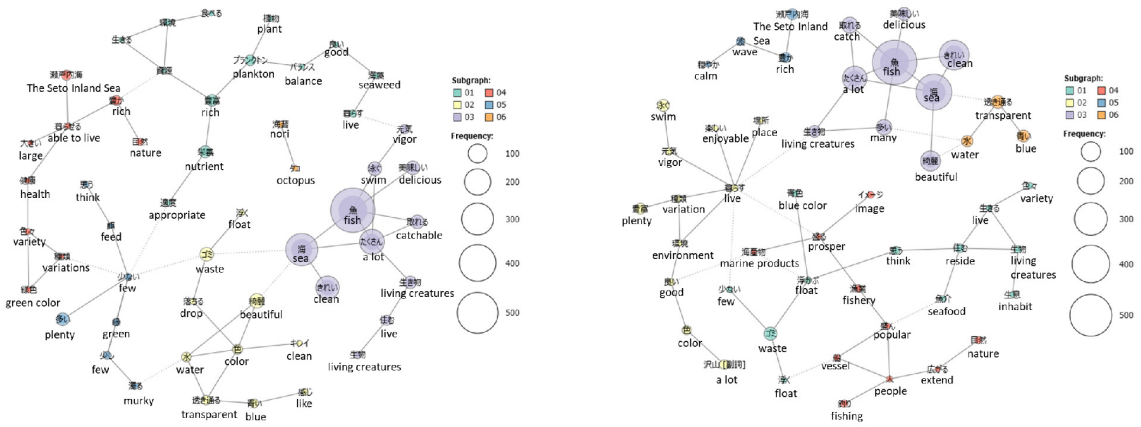

FIGURE 2
(Left) Co-occurrence network in the treatment group before the workshop. (Right) Co-occurrence network in the treatment group after the workshop.

The impact on the shallow leverage points was also mixed, though it was considered relatively easy to change (Abson et al., 2017). The preference for fish dishes changed slightly (ATET = 0.043 on a scale of 1 to 5). It may not be easy to change people's food preferences by one on-site fish workshop. However, the percentage of fish eaten within the previous week increased from 15.3% to 19.9% (ATET = 0.054). One caveat is that some of the increase may be ascribed to their increased awareness of local fish, as the "I don't know" percentage decreased similarly (see Supplementary Material for the detail).

It should also be noted that the current levels of leverage points are also important for policymakers. The support for the five measures was, on average, above "3. Neither" from 3.973 to 4.465, indicating their overall support, which aligns with a survey of the same measures as adult residents (Uehara and Hidaka, 2023). Similarly, pro-SESs, indicating direct support (i.e., involvement) for the coastal management to realize the desirable state of the SES, were favored (i.e., with the mean values above "3. Neither"), which is in line with a survey of adults (Uehara and Hidaka, 2023).

In addition to the impact on students, the survey indicated that the workshop might have improved their families' understanding, as most students shared their experiences. Although beyond the scope of our study, it may be interesting to assess spillover effects.

5 Conclusion

Our preliminary study found that an on-site fish workshop improved elementary and junior high school students' knowledge, attitudes, intentions, and behaviors regarding the sea. The assessment used a leverage point perspective and revealed that the impacts ranged from shallow to deep leverage points for sustainability transformation, including HNC, support for ongoing management measures, and pro-SES attitudes and intentions. Therefore, the on-site fish workshop strengthened their connection to nature and enhanced their understanding of and support for CZM.

Our empirical findings add to the literature on the impact of environmental education on children's understanding of and support for SES management by reconnecting them to nature. The DD design enabled us to elicit the workshop's impact more rigorously than studies with only a before-and-after or treatment-control design. The leverage points perspective guided us to identify the aspects of children's changes that are key to sustainability transformation.

This study has three policy implications. First, the improvement in leverage points demonstrated that the workshop improved the children's understanding of and support for CZM. Second, however, it should be noted that the degrees of impact on the leverage points varied. Third, some leverage points may be further improved if additional explanations are provided during the workshop. For example, ongoing management measures were not explained in the workshop. Multi-disciplinary education programs, such as using e-games, could effectively improve students' understanding (Alves et al., 2021).

Furthermore, three limitations should be addressed in future studies. First, although the leverage point perspective categorizes them from shallow to deep leverage points by the impact on the system, it is difficult, if not impossible, to know how each improvement measured by ATET contributes to the sustainability transformation of the coastal zone through a better understanding and support for the CZM. Second, while the leverage points perspective argues that they interact with each other so that improvement in the relationship with the sea is assumed to influence other leverage points (Fischer et al., 2022), this preliminary study did not empirically test how they interacted. Therefore, the impact of improving children's connectedness to the sea (e.g., "Relationship with the SIS") on the understanding of and support for ongoing management measures via interacting with other leverage points remains hypothetical. Third, this study did not investigate how sharing workshop experiences affected families; this

is critical because adults often make purchasing decisions (e.g., whether to buy local fish) and cook meals.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because this is not mandatory at my university. In consultation with Mr. Hideki Takami, principal of Tomiai Elementary School, where we conducted a nonparticipant observation of the workshop for the study design, we decided to obtain written informed consent from the principals of the schools participating in the survey on behalf of the students. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements because we obtained written informed consent via email from the principals.

Author contributions

TU: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. ST: Conceptualization, Data curation, Formal analysis, Writing – review & editing. TH: Conceptualization, Funding acquisition, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2025.1415118/full#supplementary-material

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