



Regional comparison of the structure of human well-being related to ecosystem services in coastal areas of Japan: possible effect of anxiety unique to the ria coast

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Abstract

People living in coastal areas have the advantage of accessing a high level of ecosystem services, but are also exposed to the dangers inherent in living by the sea in an area prone to natural disasters. To achieve sustainable utilization of the high ecosystem services of coastal areas, establishment of an effective marine policy based on regional characteristics of human–nature interactions is essential. We compared the structure of perceived satisfaction for five components of human well-being (‘Security’, ‘Basic material for a good life’, ‘Good social relations’, ‘Health’, and ‘Freedom of choice and action’) derived from coastal ecosystem services among three sites in Japan (Wakasa, Sanriku, and Shima) that share the same natural and social backgrounds: highly dependent on fisheries industry, located in the same climate regime (temperate zone), and have similar topographical features (ria coast). Structural equation modeling using the results from questionnaire surveys showed that the three sites shared a common basic structure of the interactions among the five components of human well-being. However, the intensity of interactions among components differed among the three sites. Questionnaire surveys on anxiety about natural disasters and future access to marine ecosystem services were simultaneously conducted at the three sites. The site-specific anxieties were responsible for the difference in the interactions among the five components of human well-being. We propose a method that quantitatively evaluates both positive (satisfaction) and negative (anxiety) aspects of respondents’ subjective assessment as a useful tool for understanding the diversity of human–nature interactions caused by the region-specific natural and social backgrounds of coastal areas.

Keywords Aquaculture · Earthquake · Fisheries · Geology · Global warming · Tsunami

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Introduction

Marine coastal areas provide high ecosystem services, supported by high biodiversity and biological production (Costanza et al. 1997; Kumar 2012). However, deterioration of biodiversity and environmental conditions have led to a decline in the ecosystem services of coastal areas around the world (Costanza et al. 2014; Steffen et al. 2015). In the next few decades, humans will increasingly become dependent on coastal areas, where more than half of the world’s population is predicted to live (Kjerfve et al. 2022; MEA 2003). It is essential to establish effective marine policies for conservation of environmental conditions and biodiversity so that humans can sustainably use the high ecosystem services of coastal areas in the future (Pascual et al. 2023; Saito et al. 2019).

In recent years, as a method of analyzing the human–nature interactions, socio-psychological research

to evaluate human well-being provided by ecosystem services has progressed (Dasgupta 2001; Partelow 2018). An approach based on people's subjective assessments of various aspects, as well as the economic evaluation, is an important component that leads to a comprehensive understanding of the value of nature (Díaz et al. 2015; Halpern et al. 2012; Hashimoto et al. 2015). The Millennium Ecosystem Assessment (MEA 2003) classified human well-being provided by ecosystem services into five major components: 'Security', 'Basic material for a good life', 'Good social relations', 'Health', and 'Freedom of choice and action'. Subjective satisfaction by local residents with these five components influences each other, and interactions among these components varies depending on region and country affected by the natural and social properties (Hori and Makino 2016, 2018; Hori et al. 2017). Furthermore, these studies commonly indicated that the anxieties about the risks associated with the use of marine ecosystem services in each region (e.g., issues associated with severe weather, natural disaster, global environmental change, marine accident, national defense, fisheries production, etc.) would be responsible for the regional differences in the structure of human well-being perceived by the residents in the coastal areas (Hori and Makino 2016, 2018; Hori et al. 2017). An accurate understanding of regional variations in human–nature interactions can contribute to the clarification of effective marine policy for each region, by which people can sustainably use the high value of coastal ecosystem services and obtain a high degree of human well-being (IPBES 2022; Partelow 2018; UNESCO-IOC 2022). To date, however, there is no quantitative data on or analysis of the anxiety about the risk in relation to regional differences in the structure of human well-being. Furthermore, in all these previous studies, the study sites included coastal areas with different topographies and marine environments.

A ria, which comes from Galician 'ría' meaning river, is formed as drowned river valleys (Fairbridge 1968). In the western North Pacific, which has diverse topographic and marine environmental features, there are areas with ria coasts consisting of highly complex coastlines and inner bays (Goudie 2018). The mixture of different topographic and environmental conditions provides marine organisms with diverse habitats, resulting in high biodiversity and production (Ribeiro et al. 2006). The intricate inner bays serve as good natural harbors and are useful for the shipping industry and trading. The quiet inner bays enable intensive aquaculture production (Vaz et al. 2021). On ria coasts, generally, human use of natural resources can be more diverse compared to areas with a more monotonous coast.

In contrast to the abundant benefits, intricate inner bays can raise anxiety of the residents related to marine nature and ecosystem services. For example, among natural disasters in coastal areas, damage caused by tsunamis tends

to be greater when the sea surface is narrower or sea depth is shallower in the inner part of the bay (Koshimura and Shuto 2015). Natural disasters such as earthquakes and tsunamis have greatly affected the coastal area of the western North Pacific because this area is located close to the boundary of multiple plates in the Circum-Pacific belt (Ring of Fire: Endo and Oh 2018). Huge earthquakes have occurred frequently due to crustal movements, some of which have caused tsunamis (Suzuki 2021). Therefore, earthquakes and tsunamis are great natural threats to local residents along the coastal area of the western North Pacific.

The present study aims to establish a quantitative social–ecological tool that enables us to examine the backgrounds of the diversity of the structure of human well-being in coastal areas. We conducted a questionnaire survey using the satisfaction for the five components of human well-being defined by MEA applying the methodology established in the previous studies (Hori and Makino 2016, 2018; Hori et al. 2017), combined with an additional survey about anxiety using the same respondents. To validate the subjective factors responsible for regional differences in the structure of human well-being, we conducted a questionnaire survey at three ria coasts in the western North Pacific that share similar natural and social features. We examined whether the combined analysis of positive and negative subjective assessments (satisfaction and anxiety) perceived by residents is useful for understanding the background that generates the diversity of human–nature interactions in the coastal area.

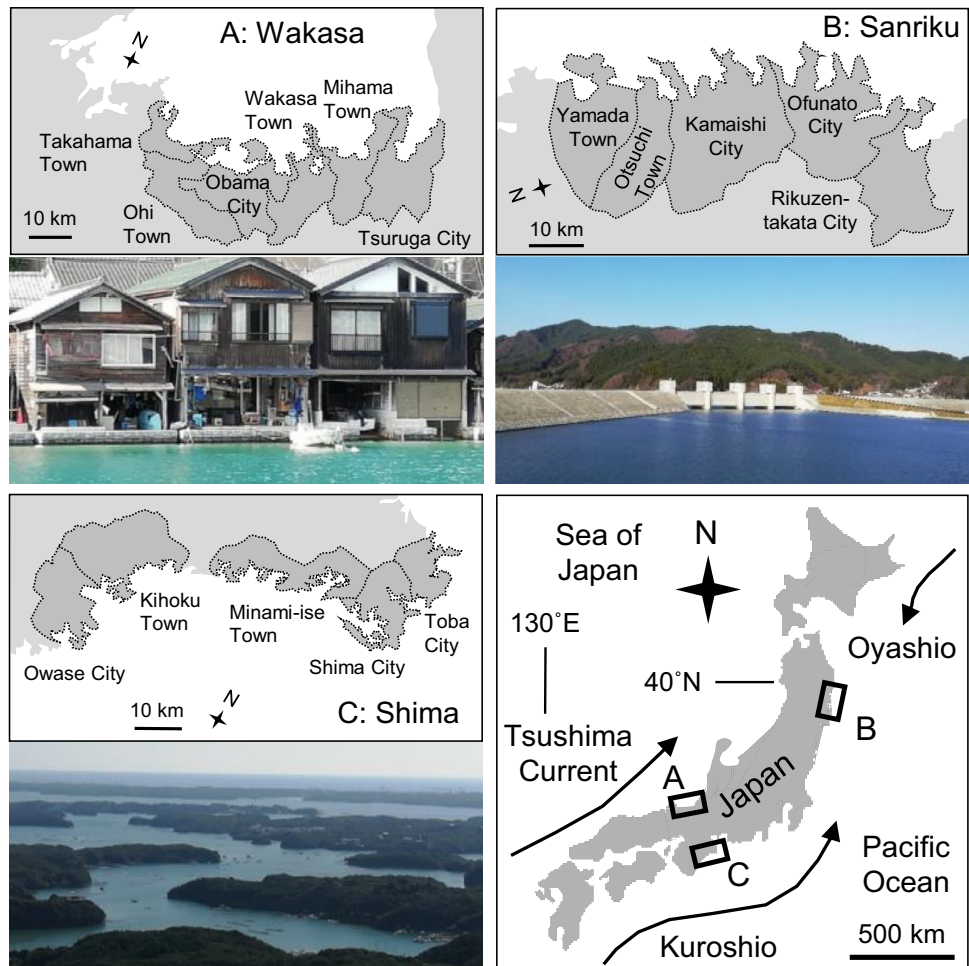
Materials and methods

Study sites

Three survey sites (Wakasa, Sanriku, and Shima areas: Fig. 1) were selected referring to their natural (geographic and oceanographic) and social commonalities for a regional comparison within Japan: all sites have similar topographical features (ria coast), are located in the same climatic regime (temperate coasts of the western North Pacific), and are highly dependent on the fisheries industry. On the other hand, the risk of natural disasters varies greatly depending on the topography and geographical location among the three sites as follows.

The Wakasa area faces the Sea of Japan, where set-net fisheries targeting fish migrating along the warm Tsushima Current and fish and shellfish farming are important fisheries (Shiki 1985). Along the ria in this area, the risk of tsunami is lower than in the Pacific coast of Japan because the Sea of Japan is connected to the Pacific Ocean only by narrow straits (Terakawa and Matsu'ura 2010). Some of the houses in fishing villages are built close to the coastline with the first

Fig. 1 Map showing three regions for the present survey and typical images representative of the rias coasts of each region. The areas where the questionnaire was conducted are shown in dark gray surrounded by dotted lines. **A** Wakasa, where some private houses have direct access to the sea from the ground floor with less anxiety about tsunamis along the coast of the Sea of Japan; **B** Sanriku, where high and thick embankments are built to reduce the effects of tsunamis; **C** Shima, where intensive aquaculture is conducted in semi-enclosed bays



floors of the houses used as work sheds or docks (Fig. 1A) because the tidal range is small (< 40 cm). Overall, people have easy access to the sea where the distance between people's lives and the sea is very close. The frequency of typhoons and heavy rains, and the resulting flood damage to humans, are less in this area than in the south of Japan (Naito et al. 2022).

The Sanriku area faces the sea where the warm Kuroshio Current and the cold Oyashio Current are mixed (Kawai 1972). Both boat fishing and aquaculture are important fishery industries in this area (Miyazaki 2005). The ria coast of Sanriku area has been severely damaged every few decades by the tsunamis including those following the 2011 Tohoku Earthquake off the Pacific Coast, which had a significant impact on local communities and the underwater environment (Shoji et al. 2021; Suzuki 2021). Since the 2011 tsunami, construction of high breakwaters has been proceeding along the coastline (Fig. 1B), indicating that tsunamis caused by earthquakes are major concerns for the residents.

The Shima area is characterized by inner bays and numerous islands surrounded by complex coastlines

(Fig. 1C). It is the birthplace of pearl farming and is the third largest pearl-producing area in Japan (Atsumi 2019). The local residents are assumed to be highly conscious of water quality management and environmental issues because there have been many activities related to "Satoumi" in which the interaction between humans and ecosystems is prolonged so that biodiversity and productivity of the ecosystems increase (Matsuda and Kokubu 2016; Yanagi 2012). On the Pacific coast of southern Japan, plate movement in the area called the Nankai Trough is predicted to cause a large-scale earthquake (Nankai Trough Earthquake) and tsunamis of 10 m or higher within the next few decades with a probability of 70–80% (Mie Prefecture 2014). Concerns about possible future Nankai Trough Earthquake and tsunamis are growing among local residents in this area (Mie Prefecture 2014).

Questionnaire survey

We conducted a web questionnaire survey of 100 people who live within 50 km (i.e., an hour's drive) from the sea at each site to minimize bias of respondents among stakeholders (fisheries, manufacturing industry,

tourism-related industries, etc.). At the Wakasa (Fukui and Kyoto prefectures) and Sanriku areas (Iwate and Miyagi prefectures), the coastline belongs to two prefectures, so the survey area was limited to the prefecture with the longer coastline. As a result, the survey sites in the Sanriku area are in the Iwate Prefecture (Yamada Town, Otsuchi Town, Kamaishi City, Ofunato City, and Rikuzen-takata City), and those in the Wakasa area are in the Fukui Prefecture (Tsuruga City, Mihama Town, Wakasa Town, Obama City, Oi Town, and Takahama Town), and those in the Shima area are in the Mie Prefecture (Toba City, Shima City, Minami-ise Town, Kihoku Town, and Owase City; Fig. 1). All surveys were conducted in September 2022. The average ages of the respondents were 44.6 in Sanriku, 46.7 in Wakasa, and 44.8 in Shima. Based on the census by Statistics Bureau of Japan (2022), the average age in 2020 for the three prefectures (Fukui, Iwate, and Mie, in which the three survey sites of the present study are located: Wakasa, Sanriku, and Shima) was 48.5, 50.7, and 48.4, respectively. The population density was 183.1, 79.3, and 306.8 km⁻² in the Fukui, Iwate, and Mie prefectures, respectively. The Japanese national average age was 47.6 and that of population density was 338.4 km⁻².

Satisfaction with the five components constituting human well-being

We evaluated the satisfaction with human well-being received from ecosystem services by the questionnaire survey based on the protocol detailed in the previous studies (Koyasu et al. 2012; Tsuge et al. 2011). Focusing on the five components that constitute human well-being defined in the MEA (2003), a total of 20 question items were used (S1). These consist of four items related to each of ‘Security’, ‘Health’, and ‘Good social relations’, five items related to ‘Basic material for a good life’, and three items related to ‘Freedom of choice and action’. Each question item was evaluated using five levels of satisfaction (5: satisfied, 4: somewhat satisfied, 3: neither, 2: not very satisfied, 1: not satisfied). These question items, categories, and methods have been used in previous studies that evaluated the degree of satisfaction with regard to human well-being obtained from coastal ecosystem services (Hori and Makino 2016, 2018; Hori et al. 2017). Based on the value of the response (the five levels of satisfaction) to each question item (three to five question items constitute each component), an average satisfaction score was calculated for each of the five components by respondent. The average satisfaction scores were compared among the five components within site by ANOVA, followed by Tukey’s test for multiple comparisons.

Reliability analysis

Prior to running the model, a reliability analysis was conducted to evaluate the stability and consistency of each question item within the five components of human well-being. Cronbach’s coefficient (α) was calculated to examine the stability of answers across respondents as follows:

$$\alpha = \frac{\text{number of question items within a component } (N)}{(N - 1) \times [1 - (\text{sum of the variance of the satisfaction scores of all items} / \text{variance in the sum of the satisfaction scores of all items within a component})]}$$

The model is reliable when α is higher than 0.7 (McMahan et al. 2013; Nunnally and Bernstein 1994). In the present reliability analysis, α was 0.87 for ‘Security’, 0.90 for ‘Basic material for a good life’, 0.84 for ‘Health’, 0.89 for ‘Good social relations’, and 0.79 for ‘Freedom of choice and action’. These data were therefore processed for further analysis.

Analysis of basic structure of the five components of human well-being using pooled data

Structural equation modeling (SEM; Duncan 1975; Pauksztat et al. 2022) was applied using pooled data obtained from the three sites ($n = 300$) with the average satisfaction score as dependent variables to examine the basic structure of and possible interactions among the five components of human well-being. The sample size of the present analysis met the minimum number ($n = 100$) required to perform SEM (Hirai 2012). In SEM analysis, model fit is considered to be high when the value obtained by dividing the Chi-square (χ^2) value by the degrees of freedom (df) is 2.0 or less (Rhoades and O’Leary 2007; Toyoda 2003).

The goodness of fit index (GFI), the adjusted goodness of fit index (AGFI), the comparative fit index (CFI), and the root mean square error of approximation (RMSEA) were used as indices for determining the adequacy of the model (Bronen 2015; Hu and Bentler 1999; Rhoades and O’Leary 2007). The model is reliable when GFI, AGFI, and CFI are close to 1.0, and RMSEA < 0.05 (Rhoades and O’Leary 2007; Toyoda 2003). Standardized partial regression coefficients (β) were calculated to investigate the interaction (direction and strength of effects; Oshio 2011) among the components of human well-being.

Multiple-group SEM

Multiple-group SEM was performed to compare the structure of interactions between the five components of human well-being among the three sites assuming that the data from the three sites are from different populations (Hori and Makino 2018; Koyasu et al. 2012; Schaffhuser et al. 2016). The model was run by site ($n = 100$ for each) with

the average satisfaction scores as dependent variables. The value obtained by dividing χ^2 by df was referred to check the model fitness, and GFI, AGFI, CFI, and RMSEA to see the adequacy of the model as conducted in the analysis using pooled data. β was calculated to investigate the interactions among the five components of human well-being within each site.

Regional comparison of anxiety about ecosystem services

A questionnaire survey on anxiety about natural disasters and future access to marine ecosystem services was carried out at the three sites. This survey was simultaneously conducted for the same respondents as that on satisfaction for the five components of human well-being. Previous studies (Hori and Makino 2016, 2018; Hori et al. 2017) proposed anxiety related to natural disaster, global environmental change, marine accident, national defense, access to ecosystem services, and fisheries production as responsible for the regional differences in the structure of human well-being in the coastal areas of the western North Pacific. According to these results, we designed eleven question items about anxiety for the risks associated with the use of marine ecosystem services in each region (S2). Considering the geographical characteristics of the present survey sites (ria coast: Endo and Oh 2018), questionnaires related to earthquakes and tsunamis were included. The question item about harsh climate, which was considered to be lethal for residents in Russia and Canada in the previous study (Hori and Makino 2018), was not included in the present survey because the three survey sites were located within the temperate climatic zone. A questionnaire about nuclear power generation, which is an important issue for the residents in coastal areas of Japan (Fukui Prefecture 2020), was included. Each question was evaluated by five levels (5: very anxious, 4: somewhat anxious, 3: neither, 2: hardly anxious, 1: not anxious). The average of the score and standard deviation were calculated by question item and were compared among the sites by

ANOVA, followed by Tukey's test for multiple comparisons. All statistical analyses were conducted using SPSS Statistics Version 28 (IBM), and SPSS Statistics AMOS Version 28 (IBM).

Results

Comparison of the satisfaction scores

The mean scores of satisfaction levels for 'Basic material for a good life' were highest among those of the five components of human well-being at all three sites (Wakasa, Sanriku, and Shima: Table 1). The differences between mean score for 'Basic material for a good life' and 'Freedom of choice and action' were significant at all sites ($p < 0.01$ for Wakasa and Sanriku, $p < 0.05$ for Shima). At Wakasa, the differences between scores for 'Basic material for a good life' and 'Good social relations' and between 'Health' and 'Freedom of choice and action' were also significant ($p < 0.01$ for both). The mean scores for all five components at Wakasa were the highest among the three regions.

Basic structure of the five components of human well-being

The SEM analysis performed on pooled data from the three sites showed a high fitness of the model, in which the χ^2 value was 1.696, df was 1, and consequential χ^2/df (1.696) was less than 2.0 (Fig. 2). The model also had a high reliability, where GFI = 0.998, AGFI = 0.966, CFI = 1.000, and RMSEA = 0.048. Among the five components of human well-being, 'Security' and 'Basic material for a good life' functioned as more fundamental variables affecting 'Freedom of choice and action', while 'Good social relations' and 'Health' were mediating variables for the other components.

Among the five components, there was a significant correlation between satisfactions for 'Security' and 'Basic material for a good life'. The satisfaction for 'Security' had a

Table 1 Mean and standard deviation (SD) of score by five satisfaction levels for the five components of human well-being (security, basic material for a good life, health, good social relations, and free-

Components of human well-being	Wakasa			Sanriku			Shima		
	Mean	SD	$p=0.01$	Mean	SD	$p=0.01$	Mean	SD	$p=0.05$
Security	3.488	0.660	abc	3.373	0.922	ab	3.313	0.818	ab
Basic material for a good life	3.750	0.700	a	3.524	0.917	a	3.498	0.805	a
Health	3.580	0.704	ab	3.383	0.905	ab	3.410	0.837	ab
Good social relations	3.403	0.690	bc	3.215	0.897	ab	3.270	0.833	ab
Freedom of choice and action	3.253	0.698	c	3.093	0.915	b	3.170	0.863	b

Different alphabetical characters indicate significant differences within each region at the p value shown

dom of choice and action; summarized in S1) in the three regions (Wakasa, Sanriku, and Shima)

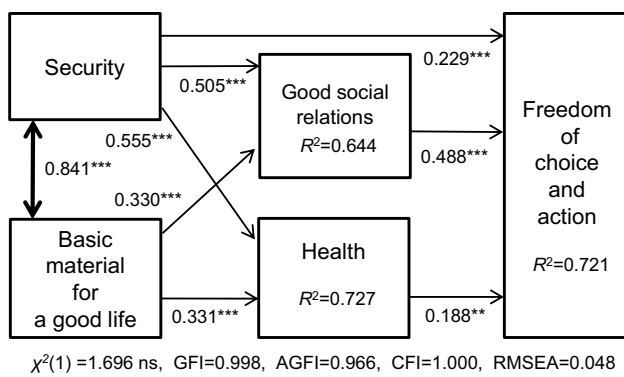


Fig. 2 Results of structural equation modeling (SEM) linkages among the five components of human well-being. All data from the three regions ($n=300$) was pooled for the analysis to investigate the basic structure of linkages among the five components. The model's best fit is shown. The thick arrow between 'Security' and 'Basic material for a good life' indicates interaction, and the numeral beside the arrow is an explanatory variable (coefficient of correlation: r). Thin arrows between the components indicate a one-way effect, and the numerals beside the arrows are structural parameters (standard partial regression coefficient: β). R^2 : explanatory variables for the factors by model; ** $p < 0.01$; *** $p < 0.001$

significant positive effect on that for 'Good social relations' and 'Health'. There was a significant positive effect of 'Security' on 'Freedom of choice and action'. 'Basic material for a good life' had a significant positive effect on 'Good social relations' and 'Health', whereas its effect on 'Freedom of choice and action' was not significant. Both 'Good social relations' and 'Health' had a significant positive effect on 'Freedom of choice and action'.

Regional comparison of the structures of the five components of human well-being

The multiple-group SEM showed a high fitness of the model, in which the χ^2 was 3.950, df was 3, and χ^2/df (1.317) was less than 2.0 (Fig. 3). The model also had a high reliability, where GFI=0.995, AGFI=0.922, CFI=0.999, and RMSEA=0.033. The basic structure of the components of human well-being at each site was similar to that derived from the analysis using pooled data from the three sites (Fig. 2), with 'Security' and 'Basic material for a good life' functioning as more fundamental variables, and 'Freedom of choice and action' as a more dependent variable.

At Wakasa, 'Security' showed the greatest influence among the components of human well-being, with significant positive effects on the mediating variables of

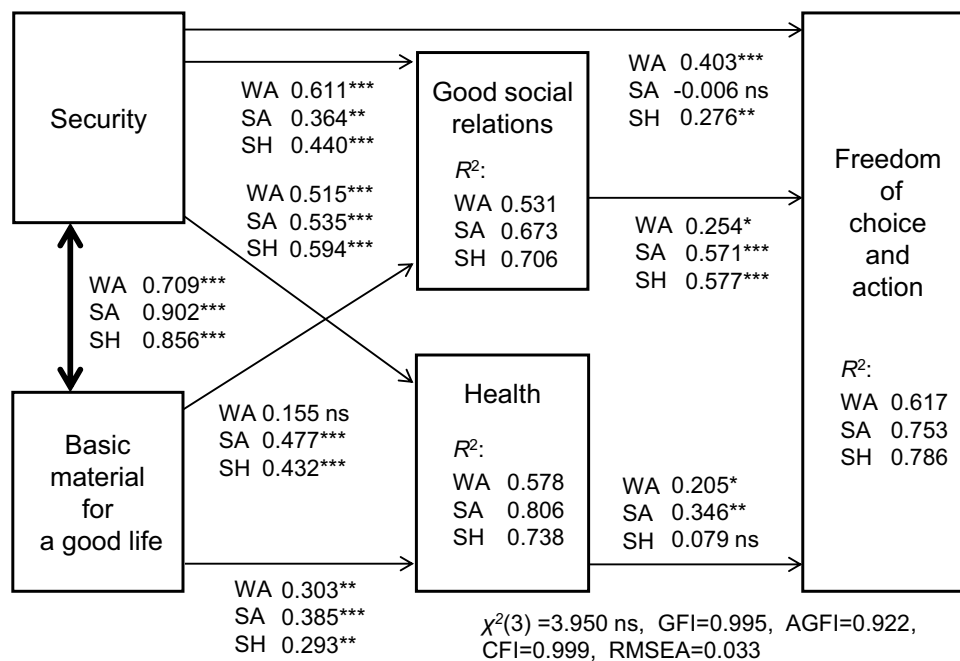


Fig. 3 Results of multi-group structural equation modeling (SEM) linkages among the five components of human well-being for the three regions (WA: Wakasa, SA: Sanriku, SH: Shima). The model was run by region ($n=100$ for each). The linkage structure among the five components for each region is expressed in the same manner as for the pooled data in Fig. 2. The model's best fit is shown. The thick arrow between 'Security' and 'Basic material for a good life' indi-

cates interaction, and the numeral beside the arrow is an explanatory variable (coefficient of correlation: r). Thin arrows between the components indicate a one-way effect, and the numerals beside the arrows are structural parameters (standard partial regression coefficient: β). R^2 : explanatory variables for factors by model; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

‘Good social relations’ and ‘Health’. The direct positive effect of ‘Security’ on ‘Freedom of choice and action’ was the greatest among the three sites. The effect of ‘Basic material for a good life’ on ‘Freedom of choice and action’ was not significant.

At Sanriku, there was no direct influence of ‘Security’ on ‘Freedom of choice and action’. The positive effect of ‘Basic material for a good life’ on the mediating variables of ‘Good social relations’ and ‘Health’ was the greatest among the three sites. There was no significant effect of ‘Basic material for a good life’ on ‘Freedom of choice and action’.

At Shima, the influence of ‘Security’ was stronger than that of ‘Basic material for a good life’, with significant positive effects on the mediating variables of ‘Good social relations’ and ‘Health’ and direct effect on ‘Freedom of choice and action’. There was no significant effect of ‘Health’ as well as ‘Basic material for a good life’ on ‘Freedom of choice and action’.

Anxiety related to ecosystem services at the three sites

Of the 11 questions on anxiety related to natural disasters and ecosystem services in coastal areas, ‘Tsunami’ and ‘Aquaculture’ showed significant differences in the scores among the three sites (Table 2). The scores for ‘Tsunami’ were lower at Wakasa than at Sanriku and Shima ($p < 0.05$ for both). The scores for ‘Aquaculture’ were lower at Wakasa than at Shima ($p < 0.05$). At Sanriku, the scores for ‘Aquaculture’ were intermediate between the other two sites without a significant difference from either of the sites.

There was no significant difference in the scores for the other nine anxiety items among the three sites. Scores for ‘Earthquake’ were the highest among the 11 question items in Sanriku and Shima. High scores for anxieties related to natural disasters and climate change, such as ‘Windstorm’,

‘Heavy rain’, and ‘Global warming’, were common in all three sites.

Discussion

Satisfaction score for the five components of human well-being

The comparison of perceived satisfaction for the five components of human well-being demonstrated that the scores for ‘Basic material for a good life’ was the highest among those for the five components at all three sites. In previous studies conducted in six countries along the rim of the Pacific Ocean (Canada, China, Japan, Korea, Russia, and USA) using the same method as the present analysis, the average score for ‘Basic material for a good life’ was the highest among those for the five components in five countries (Hori and Makino 2018). The fisheries industry utilizes the major properties of marine ecosystem services and is one of the important industries that creates jobs and supports the economy in the six countries. These socioeconomic characteristics are responsible for the high satisfaction scores for ‘Basic material for a good life’ commonly observed in the six countries (Hori and Makino 2018). The results of the present analysis also show the same results from the ria coasts of Japan, indicating that people’s lives are highly dependent on marine ecosystem services in the three sites, where fisheries are one of the major industries.

On the other hand, analysis of the satisfaction score at a regional scale within a country in the previous study showed a pattern of the satisfaction score that was different from those of the nation-scale analysis (Hori and Makino 2016). Of the five components, ‘Health’ scored the highest and ‘Security’ scored the lowest in the Hinase region in central Japan and the Ishigaki region in southern Japan, with a

Table 2 Mean and standard deviation (SD) of score by five anxiety levels related to eleven question items in relation to ecosystem and human life in coastal areas (summarized in S2) in the three regions (Wakasa, Sanriku, and Shima; $n = 100$ for each)

Question items	Wakasa		Sanriku		Shima	
	Mean	SD	Mean	SD	Mean	SD
Earthquake	3.660	0.831	3.870	1.022	3.900	0.969
Tsunami	3.28 ^a	0.986	3.68 ^b	1.136	3.88 ^b	0.956
Windstorm	3.750	0.821	3.620	1.062	3.730	0.952
Heavy rain	3.760	0.866	3.690	1.051	3.730	0.874
Provisioning services	3.360	0.938	3.370	1.089	3.340	0.924
Aquaculture	3.01 ^a	0.893	3.07 ^{ab}	1.085	3.36 ^b	0.959
Cultural use	3.070	0.891	3.080	1.041	3.280	0.889
Global warming	3.620	0.908	3.640	1.115	3.640	0.990
Marine accident	3.160	0.896	3.090	1.232	3.200	0.995
Nuclear power plant	3.460	1.068	3.140	1.271	3.140	1.092
National defence	3.430	0.902	3.410	1.138	3.440	0.998

Different alphabetical characters indicate significant differences among the regions: $p < 0.05$

significant difference within each region. ‘Security’ refers to the safety of individuals and property, assurance of access to necessary resources, and absence of damage from natural or anthropogenic disasters (MEA 2003). The low satisfaction scores for ‘Security’ in Hinase and Ishigaki suggest that people actively utilize a variety of coastal ecosystem services and are exposed to high risks of accidents associated with shipping and tourism as well as fisheries (Hori et al. 2017; Sato et al. 2020).

In the present study, the scores for all five components in Wakasa were highest among the three sites, indicating that people in this region generally perceive high levels of satisfaction from marine ecosystem services, although the results comparing only absolute values of the scores require careful interpretation. The Wakasa area constitutes the southern part of the Fukui Prefecture, which has been ranked as the first among 47 prefectures of Japan for six consecutive times (2012, 2014, 2016, 2018, 2020, and 2022: The Japan Research Institute 2022) in the Prefectural Happiness Ranking (survey every 2 years since 2012). In this survey, 80 objective indicators related to ‘health’, ‘culture’, ‘work’, ‘lifestyle’, and ‘education’ were evaluated. These objective data are responsible for the high levels of satisfaction in Wakasa found in the present study.

Basic structure of interactions among the five components of human well-being

The interactions among the five components of human well-being demonstrated by the SEM analysis using pooled data in the present study was the same as those reported in the previous studies in six countries along the rim of the Pacific (Hori and Makino 2018), three countries in East Asia (Hori and Makino 2016), and two regions in Japan (Hori et al. 2017). These interactions shared a common basic structure, in which the perceived satisfaction for ‘Security’ and ‘Basic material for a good life’ as explanatory variables amplified that of ‘Freedom of choice and action’ through influencing ‘Health’ and ‘Good social relations’ as mediating variables. In this hierarchic structure, satisfaction with ‘Security’ and ‘Basic material for a good life’ work as more fundamental variables and are essential to increase satisfaction of ‘Freedom of choice and action’. The correlation between satisfactions for ‘Security’ and ‘Basic material for a good life’ indicates that the coexistence of the economic development of the fisheries industries and the enhancement of infrastructure to maintain safety from natural disasters and stabilization of fisheries management is universally needed, regardless of country or region (Hori and Makino 2016, 2018; Hori et al. 2017, present study). The robustness of the basic structures of human well-being observed commonly in the

previous and the present studies should be tested in future research by collecting data from more regions and countries.

In the present analysis for the ria coasts, there was no direct effect of the satisfaction of ‘Basic material for a good life’ on that of ‘Freedom of choice and action’, while satisfaction for ‘Security’ had a direct positive effect on that of ‘Freedom of choice and action’ as shown in previous studies (Hori and Makino 2016, 2018; Hori et al. 2017). These results indicate that, as a trend across the three sites, satisfaction for the physical needs of using and consuming marine ecosystem services such as fishery products is not enough to improve those for ‘Freedom of choice and action’. There are several social psychological studies that have shown that economic satisfaction alone does not directly lead to improvements in human well-being (Brickman and Campbell 1971; Easterlin 1974). The present and these previous studies commonly showed that satisfaction of the multiple components of human well-being are necessary for improvement of satisfaction for ‘Freedom of choice and action’ as a dependent variable in the interactions among human well-being in coastal areas.

Regional characteristics and factors affecting the interactions among the five components of human well-being

Previous studies suggested that high anxieties related to ‘Security’ and ‘Health’ due to marine accidents and harsh climate caused the spatial difference in structure of human well-being (Hori and Makino 2018; Hori et al. 2017). However, these previous studies have not provided empirical data to discuss national or regional characteristics of the structure of human well-being. The present results from the analysis on anxiety provides evidence by which we can explain the regional variety in the structure of human well-being at the three sites.

Wakasa

In Wakasa, satisfaction for ‘Security’ had significant direct and indirect positive effects on that of ‘Freedom of choice and action’ as the dependent variable through significant positive effect on ‘Good social relations’ and ‘Health’ as mediating variables. This structure of human well-being indicates that ‘Security’ is an important component for high satisfaction for ‘Freedom of choice and action’. The scores for anxiety about tsunamis were significantly lower in Wakasa than in the other two sites, while the difference in those about earthquakes were not significant among the three sites. The frequency of life-threatening natural disasters such as tsunamis and typhoons is lower in Wakasa than in the other two sites (Naito et al. 2022; Yamaguchi and Maeda 2020). Earthquakes do occur, but tsunamis are

less frequent in Wakasa because this area is located along the coast of Sea of Japan (Terakawa and Matsu'ura 2010). These geographical and topographic properties of Wakasa would have caused the higher level of satisfaction for 'Security', lower level of anxiety for natural disasters, and the significant role of 'Security' in the hierarchic structure of human well-being.

On the other hand, the influence of 'Basic material for a good life' on 'Good social relations' was not significant only in Wakasa among the three sites. Sanriku is highly dependent on the fisheries industry (Miyazaki 2005), and Shima has complex ria coastlines where intensive aquaculture is operated (Matsuda and Kokubu 2016). In Wakasa, compared to these other two areas, the electric power industry related to nuclear power generation and utilization of cultural services through marine leisure is relatively important (Fukui Prefecture 2020). Therefore, application of tools to quantitatively analyze both the positive and negative subjective aspects would be useful, so that we can evaluate how the diverse interactions among various stakeholders influence the structure of human well-being.

Sanriku

In Sanriku, the basic structure of the interaction among the five components of human well-being was generally similar to that of other sites, with an exceptional and unique characteristic in which there was no direct effect of 'Security' on 'Freedom of choice and action'. This result indicates that the relatively low level of satisfaction for 'Security' in Sanriku has less impact on other components, and that increasing satisfaction for 'Security' does not necessarily lead to increasing satisfaction for 'Freedom of choice and action'. The regional comparison also showed that the anxiety about tsunamis was significantly higher in Sanriku than in Wakasa, providing evidence of the high awareness for the prevention of major natural disaster (Ishimura and Yamada 2021): in other words, low satisfaction for 'Security' in Sanriku. The development of social conditions, such as town planning with disaster prevention as a priority, including construction of embankments to mitigate the effects of tsunamis and the relocation of residences to ground at higher altitudes, have been considered to affect the degree of concern perceived by residents for natural disasters (Yamamoto et al. 2019; Yokouchi et al. 2015).

The positive effects of satisfaction for 'Basic material for good life' on those of 'Good social relations' and 'Health' in Sanriku were greatest among the three sites. Satisfaction for 'Basic material for a good life' can be essential as a fundamental variable that enhances the satisfaction for other components because fishery is important as a basic industry of this area (Miyazaki 2005). The significant

positive effect of the satisfaction for 'Basic material for good life' on that of 'Good social relations' would indicate that fisheries activities have a strong impact on local human relations in this region, where many small fishing villages are isolated on the coast as in Shima (Hirata 2023). In an area like Sanriku where there is a high risk of tsunamis and diverse stakeholders, accumulation of quantitative data by subjective surveys of both positive and negative aspects about 'Security' and 'Good social relations' are indispensable for understanding the regional characteristics of the structure of human well-being.

Shima

In Shima, the basic structure of the interactions among the levels of satisfaction for the five components of human well-being is similar to those of other regions. In particular, there were significant positive effects of satisfaction for 'Security' on those for 'Good social relations', 'Health', and 'Freedom of choice and action', which were common with those at Wakasa. Intensive aquaculture is operated in the calm inner bays of the ria coast in the Shima region (Fig. 1C). A high level of satisfaction with the advanced use of coastal resources in semi-enclosed bays reflects the natural and sociological background of the region. On the other hand, the results of the questionnaire survey on anxieties showed that the score for 'tsunami' in Shima was significantly higher than that in Wakasa. In the Shima area, the Nankai Trough Earthquake, which is predicted to occur in the next few decades, has been increasing people's concern about tsunamis (Mie Prefecture 2014). Compared to the huge damage caused by repeated occurrences of tsunamis in the Sanriku region, the influence of the anticipated future Nankai Trough Earthquake and ensuing tsunamis on people's anxiety for disaster may be small so far. In the future, however, the anxiety for the Nankai Trough Earthquake would become a major concern in the coastal areas of Shima and affect the interactions among satisfactions for the five components of human well-being.

Another characteristic of the results from Shima was the absence of a significant effect of satisfaction for 'Health' on 'Freedom of choice and action'. Along the ria coast in Shima, where intensive aquaculture has been operated, degradation of water quality and bottom sediment, depletion of dissolved oxygen (Takahashi et al. 2002), and red tides (Go et al. 2016) have occurred more frequently compared to Wakasa and Sanriku. Concern about the marine environment has been gradually getting greater through high activities for environmental conservation by the local residents (e.g., satoumi: Matsuda and Kokubu 2016). The results of the present survey on anxiety show a high degree of concern about future 'aquaculture', indicating the characteristic of the social and economic

backgrounds of the Shima area. Intensive aquaculture can increase concerns about human health through affecting water quality, because infectious diseases of pearl oysters have been common in semi-enclosed inner bays of Japan (Morizane et al. 2001). The spread of a new virus since 2019 has caused major damage to pearl oyster farming (Mie Prefecture Fisheries Research Institute 2022). After that, the domestic production of pearl oysters significantly decreased and imports increased (Yoshinaga and Hanami 2018). Prevention of epidemics is becoming a major theme in the aquaculture industry, with development of laws on the fisheries trade system. In Shima, therefore, accumulating quantitative data related to ‘Security’ and ‘Health’ from both positive and negative aspects (e.g., satisfaction and anxiety about future earthquakes and tsunamis, and water quality) would be a powerful tool to understand human–nature interactions in future studies.

Conclusions

We simultaneously conducted questionnaire surveys on satisfaction and anxiety for the same respondents at three sites of the ria coast in the western North Pacific to develop a tool to understand the natural and social backgrounds that cause regional differences in the structure of human well-being. The differences in the interactions among the five components of human well-being reflected the characteristics of the natural and social properties of each site. The combined analysis of satisfaction and anxiety was effective as a tool to explain the regional differences in the structure of human well-being, although it was based on quantitative evaluation in the present study. In future studies, setting questionnaire items related to anxiety corresponding to the five components of human well-being will enable quantitative evaluation of the interaction between the positive and negative subjective assessments in coastal areas. This approach of comprehensive evaluation of residents’ subjective assessments is a useful tool for understanding the diversity of human well-being and a variety of local natural and social backgrounds, so that it will be an important step toward effective policy making to archive sustainable use of the ecosystem services in the coastal area.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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