MARINE DEVELOPMENT

RESEARCH

Residents' pro-environmental behaviors in marine environmental protection

Zhihua Xu[1,2], Yue Lin[1], Shuqin Li[1*] and Yiming Huang[1]

Abstract

Guiding the public to implement pro-environmental behaviors (PEBs) is an important tool in protecting the marine environment. Based on a survey of 418 citizens in Qingdao, the public's behavioral attitudes and media concerns are introduced to expand the traditional norm activation model (NAM) to understand the public's PEBs to give references in constructing an effective public participation mechanism in marine environmental protection. The results reveal that most residents express a strong willingness to implement all types of PEBs, with a notable preference for recycling behaviors, followed by accommodating, public, and consuming behaviors. The extended NAM is found to be particularly effective in explaining accommodating and public behaviors. Personal norms can affect PEBs directly, whereas perceived responsibility and media concerns exert indirect effects on PEBs. Meanwhile, there are some differences in the formation mechanism among different behaviors. This research is conducive to understanding the public's PEBs and thereby improving public participation in marine environmental protection.

Keywords Marine environment protection, Norm activation model, Pro-environmental behaviors, Public participation

1 Introduction

In recent years, China's coastal ecological environment has improved steadily, as evidenced by the ongoing trend of increasing the proportion of good water quality (Zhang et al., 2022), which reached 85.0% in the nearshore sea area in 2023, and the attendant progress in coastal restoration efforts (Liu, et al. 2020a). However, the problems of marine environmental pollution and ecological degradation are still serious in China, reflected in the increasing incidence of plastic in marine litter (Cui, 2024) and declining marine biodiversity (Liu, 2013). Public participation is considered to be an important force in strengthening marine environmental governance due to its crucial role in addressing the efficacy and fairness of environmental policies (Gao et al., 2023). China is actively promoting the construction of a modern environmental governance system that emphasizes the importance of public participation and aims to establish a good pattern for the whole society to participate in environmental governance. Although many previous studies have analyzed the public's pro-environmental behaviors (PEBs) (Gao et al., 2024; Kim & Koo, 2020) and provided the basis for this paper, these studies have mainly focused on other areas. And the current situation and influencing factors of the public's PEBs in marine environmental protection are still not clear. This study extends the baseline norm activation model (NAM) by incorporating behavioral attitudes and media concerns, aiming to propose solutions to these problems and deepen the understanding of the public's PEBs. It is of significant practical importance for establishing effective mechanisms for public participation in marine environmental protection, thereby improving the performance of marine ecological governance effectively.

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The contribution of this paper to the relevant literature is mainly reflected in the following two aspects. First, there are several previous studies on marine environmental protection from the perspective of macro management strategies (Day et al., 2008; Lu et al., 2024; Ortiz-Lozano et al., 2017), and there are several previous studies on the willingness to pay for marine environmental protection at the individual level (Manson et al., 2021; McKinley & Fletcher, 2010; Xu et al., 2024a, 2024b). In addition, PEBs, which generally refers to positive behaviors by the public to promote sustainable development or reduce negative impacts on the environment (Blamey, 1998; Kollmuss & Agyeman, 2002), has already been applied in many fields, e.g., energy use (Mtutu & Thondhlana, 2016), commodity consumption (Welsch & Kühling, 2010), and product recycling (Koo, 2000). However, the research on the public's PEBs concerning marine environmental protection is still somewhat sparse. This paper investigates eight behaviors of the public and classifies them into four types, including recycling behaviors, consuming behaviors, accommodating behaviors, and public behaviors, which are conducive to improving related research on the public's PEBs in marine environmental protection.

Second, it is necessary to explore the influencing factors of the public's PEBs in marine environmental protection to then guide the public's PEBs. These factors can be mainly divided into individual factors and social factors, among which individual factors include sociodemographic variables and psychological variables (Chan, 2001), and social factors include institutional factors, economic factors, and social–cultural factors (Harth et al., 2013). Additionally, several theoretical models have been used to address PEBs. Among them, the NAM has a wide influence because it emphasizes explaining the formation of altruistic behaviors from an ethical point of view. The NAM has been used to study various types of environmentally friendly behaviors, such as electricity-saving behaviors (Harzallah, 2010), sustainable tourism behaviors (Wu et al., 2020), and farmers' waste reduction and recycling behaviors (Savari et al., 2023). However, few articles have applied the NAM to study PEBs in marine environmental protection, and we enrich the research on the NAM in this field. Furthermore, many scholars believe that the NAM is not sufficient to fully reveal the individual's altruistic behavioral intentions and behaviors, and the model is thereby improved by introducing other psycho-cognitive factors (Onwezen et al., 2013). In general, we believe that the public's PEBs in marine environmental protection are influenced by intrinsic beliefs and extrinsic shocks. Behavioral attitudes and media concerns, which are considered an important manifestation of intrinsic beliefs and extrinsic shocks

in this paper, are introduced into the baseline NAM to enhance the explanatory power of the model, which can further explore the formation mechanism of the public's PEBs in marine environmental protection.

2 Theoretical framework and hypotheses

PEBs, which are activities intended to address actual or envisioned problems with environmental protection (Rice, 2006), are considered to contribute significantly to marine environmental protection when residents participate in them (Wichmann et al., 2022). Nowadays, activities initiated by the public or sponsored by public welfare organizations to clean up beaches and other PEBs by the public are on the rise, which contributes to the long-term sustainability of marine ecosystems.

PEBs can be classified into intent-oriented behaviors and impact-oriented behaviors (Stern, 2000). Intent-oriented behaviors demonstrate the public's concerns and intentions for marine environmental protection. Impact-oriented behaviors, which can have a direct or indirect impact on the environment, can be classified into two categories based on their actual effect on the marine environment. Stern (2000) further subdivided impact-oriented behaviors into public-sphere behaviors and private-sphere behaviors. Public-sphere behaviors, which focus on conveying the attitude toward and concern over environmental problems, can promote environmental protection indirectly (Zhao et al., 2016) and often occur in the public sphere, including both active behaviors (e.g., active participation in environmental groups and demonstrations) and inactive behaviors (e.g., joining environmental groups and policy support) (Stern, 2000). Private-sphere behaviors, which place emphasis on the practical behaviors that improve the environment directly, refer to the practical actions taken by individuals to improve the environment directly (Rice, 2006; Stern, 2000). Private-sphere behaviors include resource conservation, green consumption, and waste separation behaviors (Huddart Kennedy et al., 2015). In this paper, we investigated eight examples of the public's PEBs and classified them into four types, namely, recycling behaviors, consuming behaviors, accommodating behaviors, and public behaviors. Meanwhile, this study endeavors to elucidate influencing factors of the public's PEBs by integrating behavioral attitudes and media concerns into an expanded NAM to offer insights for the development of an effective mechanism to engage the public in marine environmental protection.

2.1 Norm activation model (NAM)

The NAM is an important theory for studying public altruism and helping behaviors and has a good fit in explaining and predicting PEBs (Han et al., 2015). The

NAM is made up of four primary factors: behavioral tendencies, personal norms, perceived responsibility, and consequence perception. Among them, behavioral tendencies, which are generally defined as a person's preferred way of behaving, are conceptualized in this paper as the public's PEBs in marine environmental protection. Personal norms, which refer to a sense of duty or obligation to engage in or abstain from particular actions (Schwartz, 1977), are found to be a key factor in environmentally friendly behaviors (Harland et al., 1999; Schwartz, 1977). Perceived responsibility, which describes the individual's view of responsibility for unfavorable outcomes (De Groot & Steg, 2009; Hopper & Nielsen, 1991), is conceptualized in this paper as the public's sense of responsibility for the damage to the marine environment and the way it is attributed. Consequence perception refers to an individual's consciousness of the potential adverse effects or outcomes that may affect others if not conducting a specific action pro-socially or pro-environmentally (De Groot & Steg, 2009; Schwartz, 1977). Numerous studies have used the NAM to explain people's pro-environmental intentions or behaviors (Schwartz, 1977), e.g., using public transportation (Bamberg et al., 2007), energy conservation (Wittenberg et al., 2018), and electric vehicle adoption (Singh et al., 2023). The majority of studies have demonstrated that personal norms have a direct impact on PEBs and are determined by consequence perception and perceived responsibility (Schwartz, 1977; Schwartz & Howard, 1982). Meanwhile, perceived responsibility is considered to be directly and positively impacted by consequence perception (Schwartz, 1977; Zhang et al., 2013). This study posits that when members of the public recognize the significant benefits of implementing PEBs in the context of marine environmental protection, they will develop a strong sense of responsibility and form proactive personal norms. This, in turn, increases the likelihood of adopting PEBs. Therefore, we propose the following four hypotheses.

> H1a: The stronger the public's personal norms, the more willing they are to implement PEBs in marine environmental protection.
> H1b: The public's perception of the consequences of implementing PEBs in marine environmental protection has a positive impact on personal norms.
> H1c: People who perceive a strong responsibility for implementing PEBs in marine environmental protection would show a high level of personal norms.
> H1d: The stronger the public's perception of the consequences of implementing PEBs in marine environmental protection, the stronger the perceived responsibility.

2.2 Behavioral attitude

Behavioral attitude refers to the degree to which an individual develops a favorable or unfavorable evaluation or assessment of behavior after analyzing its characteristics (Ajzen, 1991; Marcinkowski & Reid, 2019). Behavioral attitudes have a significantly positive effect on PEBs (Liu et al., 2020b). Meanwhile, behavioral attitudes are found to have a close relationship with the NAM elements (Bamberg & Möser, 2007; Klöckner, 2013). Personal norms are found to have a close and positive relationship with the public's attitudes toward environmental issues, thereby motivating the public to implement green behaviors (Van Tonder et al., 2023). Furthermore, perceived responsibility is also a crucial antecedent of pro-environmental attitudes and behaviors (Syropoulos & Markowitz, 2022). When the public has a strong sense of environmental responsibility, they will have a positive behavioral attitude toward environmental protection (Long et al., 2023). The findings of Park and Ha (2014) further demonstrated that stronger consequence perception will contribute to a more favorable behavioral attitude toward PEBs. Considering this, we put up the following four hypotheses.

> H2a: Behavioral attitude has a positive and significant impact on the public's PEBs in marine environmental protection.
> H2b: The public's personal norms have a positive impact on behavioral attitude.
> H2c: The public's perceived responsibility has a significantly positive effect on behavioral attitude.
> H2d: The stronger the public's perception of consequences, the more positive their behavioral attitude toward PEBs in marine environmental protection.

2.3 Media concern

Media concern, which refers to the level of respondents' attention to the information on the marine environment reported on television, in newspapers, and on the Internet, focuses on the onslaught of external information (Thompson-Saud et al., 2018). Media concern is considered to contribute to prompting the public to form positive values of environmental participation and enhance PEBs (Liu & Li, 2021). That is, when individuals pay more attention to media-related reports, they may take the initiative to implement PEBs in marine environmental protection. Additionally, media concern is found to present a unique and timely opportunity to encourage PEBs through personal norms (Hynes & Wilson, 2016). Discussion of marine environmental issues on social media may form social pressure on users and further elevate personal responsibility (Han et al., 2018). Media provide

information about new personal norms and persuade individuals to accept them (DellaVigna & Gentzkow, 2010). Furthermore, people may be more likely to form a negative perception of the harm if the negative information about marine pollution is not responded to appropriately (Zhao et al., 2016). That is, residents with strong media concerns may be more likely to perceive negative consequences than those with weak media concerns. Furthermore, the public's media concern is also reported to be associated with their behavioral attitudes (Liao et al., 2015). Exposure to information provided by the mass media can positively affect behavioral attitudes (Arias, 2019). Specifically, people who hold stronger perceptions of media concern tend to hold a positive behavioral attitude toward PEBs in marine environmental protection. Accordingly, the following hypotheses are proposed.

> H3a: As residents' media concern increases, PEBs in marine protection will also increase.
> H3b: Media concern has a significant impact on perceived responsibility.
> H3c: The public's personal norms are significantly influenced by media concerns.
> H3d: The higher the media concern, the stronger the consequence perception.
> H3e: Media concern has a positive impact on behavioral attitudes.

In summary, this paper extends NAM by adding behavioral attitude and media concern into the model to explore the formation of the public's PEBs in marine environmental protection, which has an important reference value for realizing scientific decision-making on

environmental protection. The details of the theoretical framework and research hypotheses are shown in Fig. 1.

3 Data
3.1 Questionnaire survey
In this study, we conducted a survey to understand the public's PEBs in marine environmental protection in Qingdao, China. The research objects were limited to those who have lived in Qingdao for more than two years to ensure that the interviewees have a good understanding of the marine environment in Qingdao. Additionally, they may implement PEBs, which can make the results of our survey more reliable. In the beginning, several pro-test questionnaire surveys were conducted in the coastal landscape playgrounds, such as Shilaoren Bathing Beach and the First Sea Bathing Beach, from August to December, 2019. Then, the questionnaire was modified based on the feedback, and the official questionnaire was released relying on the Questionnaire Star platform in Qingdao from June to July, 2020. Finally, 418 validated questionnaires were screened after data analysis.

The questionnaire was divided into five parts. The first part mainly explored basic attitudes toward marine pollution and seawater quality, i.e., the respondents were asked if they had noticed any environmental deterioration. The second part mainly investigated three latent variables in the NAM, namely, personal norms, perceived responsibility, and consequence perception. Subsequently, residents were required to show their willingness to participate in PEBs in marine environmental protection. In addition, residents' media concern and their attitudes toward PEBs in marine environmental protection were also investigated. The
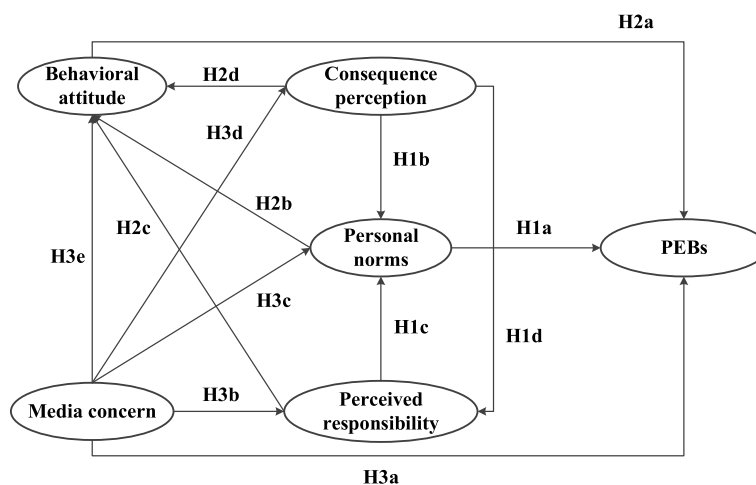

Fig. 1 Theoretical models and hypotheses

final section contained respondents' basic information, including age, gender, educational level, occupation, and annual personal income.

3.2 Measures

In this paper, private-sphere, public-sphere, and accommodating behaviors were designed to be investigated by the three specific behaviors in the initial questionnaire. However, based on the pre-survey results, we found that the three items of private-sphere behaviors did not pass the reliability test, that is, there were huge differences in the three items of private-sphere behaviors. Therefore, private-sphere behaviors were further classified into consumption behaviors and recycling behaviors. That is, PEBs were divided into four categories, namely recycling behaviors (RBs), consuming behaviors (CBs), accommodating behaviors (ABs), and public behaviors (PBs) in our final questionnaire. The RB, CB, AB, and PB were investigated by one item, one item, three items, and three items, respectively. All eight items were examined based on five-point Likert scales ranging from '1 = Very reluctant' to '5 = Very willing'. The details are shown in Table 1.

Consequence perception (CP), perceived responsibility (PR), and personal norms (PNs), which are the three latent variables in the NAM, cannot be measured directly and should instead be measured by several measurement variables. Therefore, each latent variable contained three measurement questions. In the original questionnaire, CP was investigated by residents' perception of the adverse impact of marine environmental damage on economic development, residents' quality of life, and local marine organisms. The options were set based on 5-point Likert scales from '1 = Minimal' to '5 = Maximal'. The PR and PN variables were investigated by three declarative statements, and respondents were required to give their judgment based on a 5-point Likert scale from '1 = Strongly disagree' to '5 = Strongly agree'. However, the results of the pre-survey discovered that some measurement questions measuring PR and PNs failed the convergent validity test. Therefore, these measurement variables were excised. The details of the final items of the three latent variables are presented in Table 1.

Given that respondents' PEBs may be affected by behavioral attitudes and media concerns (Bechler et al., 2021; Matthies et al., 2012), the two variables were investigated. The behavioral attitude was measured with four items based on five-point scales, e.g., 'It is a very positive behavior to conduct PEBs in marine environmental protection'. The options were set from '1 = Strongly disagree' to '5 = Strongly agree'. Media concern was measured with three items based on five-point Likert scales, e.g., 'Do you pay attention to marine environment-related reports while watching TV?'. The options are also set from '1 = Strongly disagree' to '5 = Strongly agree'. The details of behavioral attitude and media concern are also presented in Table 1.

3.3 Samples

The survey sample leans toward a female majority (64.11%) and is notably younger, with 51.9% of the participants under 30. Educational levels are high, with the majority (77.3%) reporting a bachelor's degree or higher. In terms of income, the respondents are generally well-off, with only a small percentage (20.1%) earning less than 20,000 CNY/a and a significant proportion (41.2%) falling into the 50,000 to 120,000 CNY/a. Compared to the data of the Qingdao 2021 Statistical Yearbook, the sample's educational and economic profile suggests a more affluent and educated demographic. The occupational distribution shows a strong presence in the private sector (41.87%), with a substantial number also employed in state organs and public institutions (26.79%). This demographic may be more inclined toward active participation in marine environmental protection, which is crucial for understanding their potential role in marine environmental protection efforts.

4 Results

4.1 Descriptive statistics

The results show that 74% of the respondents thought that the seawater pollution in Qingdao had worsened in the previous two years, and 59% thought that the seawater was turbid. This suggests that it is necessary to adopt measures to improve the marine environment in Qingdao. A total of 95% of the respondents believed they should bear some responsibility for protecting the marine environment. More than half of the respondents felt that damage to the marine environment harmed local economic development, quality of life, and biodiversity.

Subsequently, the respondents were required to show their intention of engaging in eight specific PEBs. The results show that most of the residents had a strong willingness to participate in all four types of PEBs in marine environmental protection, as indicated in Table 1 and Fig. 2. RBs were the most favored among the four types of PEBs, with a mean value of 4.2. Of all the respondents, 98.1% were willing to reduce the amount of rubbish thrown into the ocean. However, 52.39% of the respondents agreed to buy less seafood. This suggests that, in the face of the deterioration of the marine environment, people are reluctant to reduce their consumption of necessary goods such as food. There are also significant differences in PBs. A total of 79.43% of the respondents were willing to join environmental organizations to protect the

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Table 1 Measurement items

Variables	Item	Low (1)	High (5)	Mean (SD)
Recycling behaviors (RBs)	To protect the marine environment, are you willing to recycle newspapers, plastic, cans, and glass on the beach?	Very reluctant	Very willing	4.234 (0.701)
Consuming behaviors (CBs)	To protect the marine environment, are you willing to reduce your consumption of seafood?	Very reluctant	Very willing	3.543 (0.921)
Public behaviors (PBs)	PB1: To protect the marine environment, are you willing to write to the government department to reflect on the problem of marine pollution?	Very reluctant	Very willing	3.505 (0.835)
	PB2: To protect the marine environment, are you willing to persuade others to change their behavior?	Very reluctant	Very willing	3.782 (0.864)
	PB3: To protect the marine environment, are you willing to participate in environmental protection organizations?	Very reluctant	Very willing	4.091 (0.866)
Accommodating behaviors (ABs)	AB1: To protect the marine environment, are you willing to actively search for information about the marine environment?	Very reluctant	Very willing	3.833 (0.769)
	AB2: To protect the marine environment, are you willing to discuss the marine environment with others?	Very reluctant	Very willing	3.806 (0.864)
	AB3: To protect the marine environment, are you willing to actively pay attention to the information about the marine environment?	Very reluctant	Very willing	4.256 (0.726)
Consequence perception (CP)	CP1: Adverse impact of marine environmental damage on economic development	Minimal	Maximal	2.801 (1.05)
	CP2: Adverse impact of marine environmental damage on residents' quality of life	Minimal	Maximal	2.722 (1.06)
	CP3: Degree of adverse impact on local organisms damaged by the marine environment	Minimal	Maximal	2.292 (1.064)
Perceived responsibility (PR)	I should take some responsibility for marine environmental protection	Strongly disagree	Strongly agree	4.079 (0.863)
Personal norms (PNs)	PN1: If I do anything to destroy the marine environment, I will feel guilty	Strongly disagree	Strongly agree	3.579 (0.831)
	PN2: If I do not contribute to the protection of the marine environment, I will feel guilty	Strongly disagree	Strongly agree	4.383 (0.704)
Behavioral attitude (BA)	BA1: It is a very positive behavior to conduct PEBs in marine ecological protection	Strongly disagree	Strongly agree	3.998 (0.725)
	BA2: It is a very responsible behavior to put PEBs in marine ecological protection into practice	Strongly disagree	Strongly agree	4.074 (0.803)
	BA3: It is a very useful behavior to conduct PEBs for the protection of the marine environment	Strongly disagree	Strongly agree	3.842 (0.959)
	BA4: It is a very useful behavior to conduct PEBs for the protection of the marine environment	Strongly disagree	Strongly agree	4.007 (0.985)
Media concern (MC)	MC1: Do you pay attention to marine environment-related reports on TV?	Never	Very high	3.285 (1.03)
	MC2: Do you pay attention to the marine environment-related reports when you read official accounts?	Never	Very high	3.108 (1.082)
	MC3: Do you pay attention to marine environment-related reports when you surf the Internet?	Never	Very high	3.106 (1.055)

SD Standard deviation

marine environment, while only 50.72% were willing to write letters to the authorities about marine pollution. This may be because although the public believed that government policies help to protect the marine environment, they were skeptical about the effectiveness of sending letters to the government to promote the improvement of the marine environment. Regarding accommodating behaviors, 86.12% of the respondents tended to pay attention to marine environmental information about participating in environmental protection, which indicates that most respondents were concerned about the marine environment.

4.2 Measurement models
Before analyzing the theoretical model, the reliability and validity of each latent variable were tested, and the results
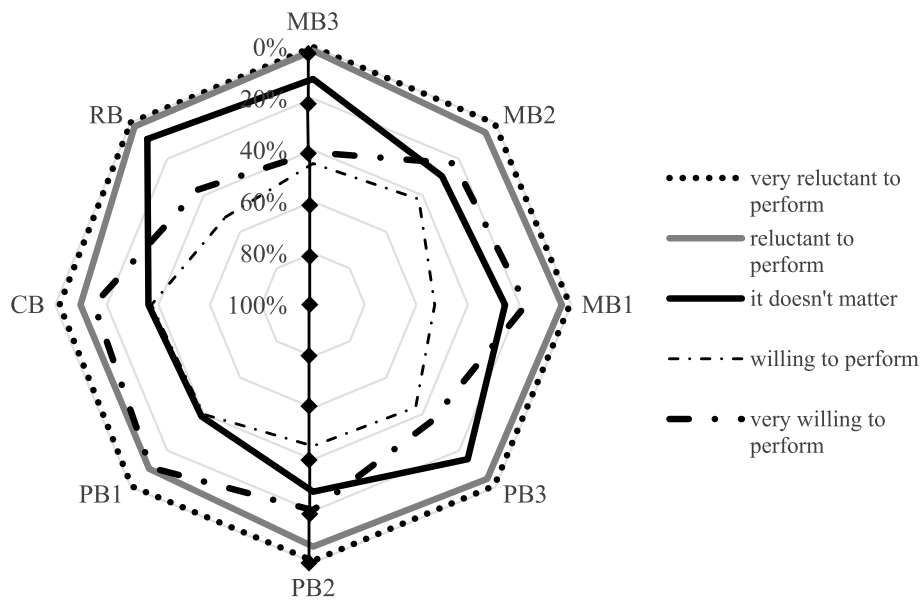
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Fig. 2 Public's PEBs in marin environment protection

Table 2 Variable reliability, validity, and factor analysis results

Item	β	AVE	CR	Cronbach's α	KMO	Bartlett's test
CP1	0.772	0.73	0.89	0.82	0.72	431.18 (p = 0.000)
CP2	0.785					
CP3	0.763					
MC1	0.806	0.75	0.90	0.84	0.73	485.48 (p = 0.000)
MC2	0.796					
MC3	0.778					
PB1	0.690	0.63	0.71	0.84	0.67	234.83 (p = 0.000)
PB2	0.722					
PB3	0.605					
AB1	0.686	0.63	0.84	0.71	0.67	229.43 (p = 0.000)
AB2	0.655					
AB3	0.670					
PN1	0.670	0.67	0.84	0.51	0.50	54.27 (p = 0.000)
PN2	0.520					
BA1	0.645	0.59	0.85	0.77	0.76	415.69 (p = 0.000)
BA2	0.614					
BA3	0.735					
BA4	0.701					

β Regression weight, *AVE* average variance extracted value, *CR* composite reliability, *KMO* Kaiser–Meyer–Olkin

are shown in Table 2. First, Cronbach's α and composite reliability (CR) were used for the reliability test. As shown in Table 3, the CR of each latent variable is greater than 0.7, and Cronbach's α is above 0.5, indicating that the data met the reliability requirements. Next, convergent validity tests were conducted. The results of the confirmatory factor analysis suggest that the values of Kaiser–Meyer–Olkin

(KMO) were all greater than 0.50, and all the *p*-values of Bartlett's sphericity test were smaller than 0.001, indicating that each latent variable was suitable for factor analysis. Further analysis showed that the standardized factor loadings of each measurement item remained in the range of 0.52–0.81, and the average variance extracted (AVE) was greater than 0.50, indicating that convergent validity

Table 3 Discrimination test

	1	2	3	4	5	6	7	8	9
1CP	**0.77**								
2PR	−0.05	**1**							
3PN	−0.02	0.11[a]	**0.60**						
4MC	−0.01	0.05[a]	0.08[a]	**0.79**					
5BA	−0.03	0.10[a]	0.09[a]	0.07[a]	**0.69**				
6RB	−0.06	0.07	0.07[a]	0.06[a]	0.04	**1**			
7CB	0.01	0.11	0.09[a]	0.05	0.09[a]	0.03	**1**		
8PB	0.02	0.15[a]	0.15[a]	0.10[a]	0.09[a]	0.12[a]	0.16[a]	**0.67**	
9AB	−0.04	0.15[a]	0.11[a]	0.09[a]	0.14[a]	0.09[a]	0.13[a]	0.19[a]	**0.67**

Bold font on the diagonal line indicates the square root of AVE values

[a] indicates passing the significance test at the 1% level

was duly verified. Finally, discriminant validity was tested. As presented in Table 3, discriminant validity was good because the AVE values were greater than the square of the correlation coefficient. In conclusion, the data pass the reliability and validity test and are suitable for further study.

4.3 Hypotheses testing

SPSS AMOS 21.0 was employed, and the maximum likelihood method was applied to estimate the structural equation models. The initial norm activation models were first applied to investigate the factors that affect the public's adoption of PEBs in marine environmental protection. The structural equation model includes dominant, potential, and error variables. The model formula is as followed:

$$x = \prod_x \xi + \delta \tag{1}$$

$$y = \Pi_y \eta + \varepsilon \tag{2}$$

$$\eta = B_\eta + \Gamma\xi + \zeta \tag{3}$$

Equations (1) and (2) are measurement equations, representing the relationship between the measured variables and the latent variables; Eq. (3) is a structural equation, representing the relationships between the latent variables; ξ represents exogenous latent variables, which correspond to the constructs of behavioral attitudes and media concerns in this study; η represents endogenous latent variables, which correspond to the constructs of CP, PR, PNs, and PEBs in this study; x and y represent the vectors of exogenous and endogenous measured variables, respectively; $\prod_x$ represents the matrix of factor loadings that represent the relationships between the exogenous measured variables and the exogenous latent variables; $\prod_y$ represents the matrix of factor loadings that represent the relationships between the endogenous measured variables and the endogenous latent variables; B and Γ represent the matrices that encapsulate the structural relationships between the endogenous latent variables and the effects of the exogenous latent variables on the endogenous latent variables, respectively; δ, ε and ζ are corresponding error terms.

The four baseline models of four different types of PEBs were first analyzed separately to test hypotheses H1a, H1b, H1c, and H1d. The results are as detailed in Fig. 3. All the models show good fitness (RMSEA < 0.08, GFI > 0.90, CFI > 0.90, IFI > 0.90, TLI > 0.90), indicating that the NAM is suitable for testing residents' willingness of PEBs for marine protection. The NAM is powerful in explaining the four types of PEBs in marine environmental protection. The explanatory powers are 16%, 11%, 65%, and 52% for RBs, CBs, PBs, and accommodating behaviors, respectively. PNs show significant impacts on PEBs at the 1% level in all four models ($\beta_{RB} = 0.40$, $\beta_{CB} = 0.32$, $\beta_{PB} = 0.80$, $\beta_{AB} = 0.70$, $p < 0.01$), which is consistent with H1a. PR also shows a significantly positive effect on PNs ($\beta_{RB} = 0.47$, $\beta_{CB} = 0.46$, $\beta_{PB} = 0.43$, $\beta_{AB} = 0.48$, $p < 0.01$), leading us to accept H1c. However, CP is not found to have close relationships with PR and PNs, rejecting H1b and H1d.

Subsequently, the extended NAM was analyzed, and the results are displayed in Table 4 and Fig. 4. The models also show good fitness (RMSEA < 0.08, GFI > 0.90, CFI > 0.90, IFI > 0.90, TLI > 0.90). These indicators in the extended models are much better than the results of the baseline NAM model. Furthermore, to a certain extent, the extended models have improved the strength of the explanation for all types of PEBs in marine environmental protection apart from CBs. The explanatory powers were 17%, 11%, 68%, and 54% for RBs, CBs, PBs, and accommodating behaviors, respectively. Additionally, compared with the results of the initial NAM, there were no significant changes in the role of the NAM elements in the extended NAM. PNs still have significant impacts
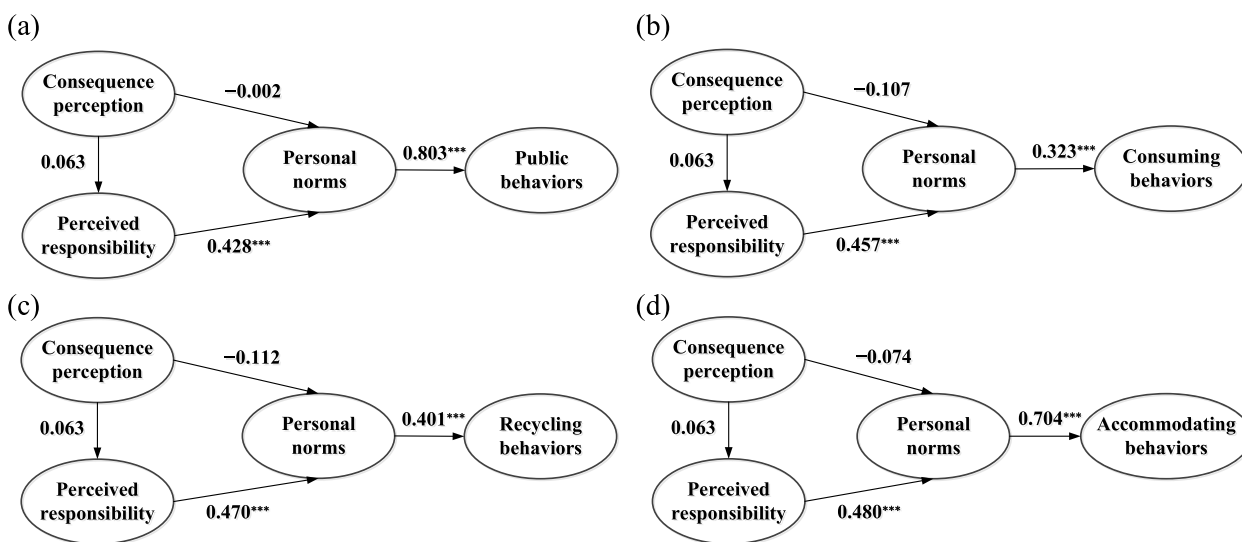
(a)

(b)

(c)

(d)

Fig. 3 Baseline model. $^{***}p < 0.01$

Table 4 Results of the structural model of the four PEBs based on the NAM and the expanded NAM

Paths	RB			CB			PB			AB		
	UE	CR	SE	UE	CR	SE	UE	CR	SE	UE	CR	SE
H1a	0.434	2.876	0.346**	0.542	2.533	0.319	0.905	4.920	0.937***	0.414	3.100	0.436**
H1b	0	0.070	0.001	0	0.155	0.002	0.002	0.830	0.013	0	−0.125	−0.002
H1c	1.466	3.569	0.457***	1.463	3.589	0.469***	1.477	3.691	0.453***	1.523	3.644	0.464***
H1d	−0.002	−1.139	−0.030	0.002	1.140	0.029	0.002	1.072	0.030	0.002	0.672	0.032
H2a	−0.036	−0.289	−0.026	0.084	0.488	0.045	−0.218	−1.585	−0.196	0.316	2.749	0.283**
H2b	0.424	2.829	0.476*	0.448	2.815	0.492*	0.424	3.104	0.488**	0.413	2.656	0.487**
H2c	0.185	0.534	0.065	0.153	0.429	0.054	0.164	0.525	0.058	0.149	0.415	0.053
H2d	0	−0.184	−0.002	−0.001	−0.252	0.003	−0.002	−0.655	−0.009	−0.001	−0.244	−0.003
H3a	0.103	1.652	0.120*	−0.041	−0.478	−0.036	0.001	0.015	0.001	0.113	2.125	0.173**
H3b	0.066	2.901	0.311**	0.066	2.907	0.310**	0.067	2.977	0.311**	0.065	2.890	0.309**
H3c	0.276	4.404	0.404***	0.269	4.271	0.403***	0.290	4.817	0.415***	0.281	4.516	0.409***
H3d	−0.018	−0.392	−0.005	−0.018	−0.398	0.005	−0.019	−0.409	−0.005	−0.020	−0.437	−0.006
H3e	0.092	1.691	0.151*	0.089	1.599	0.146	0.088	1.587	0.144	0.086	1.570	0.147

RB Recycling behavior, *CB* Consuming behavior, *PB* Public behavior, *AB* Accommodating behavior, *UE* Unstandardized estimate, *CR* Critical ratio, *SE* Standardized estimate

$^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

on PEBs, and PR is also found to have a close relationship with PNs at the 1% level in all four models. CP still does not show significant effects on PR and PNs.

Subsequently, the role of behavioral attitude was tested. In the four extended NAM variables, behavioral attitude only showed a positive effect on accommodating behaviors ($\beta_{AB} = 0.283$, $p < 0.05$), and the effects on the other three types of PEBs were not significant, therefore rejecting H2a. The relationship between the NAM variables (PNs, PR, and CP) and behavioral attitude was also explored. The public's behavioral

attitude was significantly and positively influenced by PNs ($\beta_{RB} = 0.476$, $\beta_{CB} = 0.492$, $\beta_{PB} = 0.488$, $\beta_{AB} = 0.487$, $p < 0.10$). That is, PNs act as drivers of behavioral change, prompting the public to demonstrate more responsible attitudes when confronted with marine environmental issues, thereby confirming H2b. However, the connection between respondents' behavioral attitudes and PR is not found in all four models, which is not consistent with H2c. Furthermore, the effect of CP on behavioral attitude is also insignificant, therefore rejecting H2d.
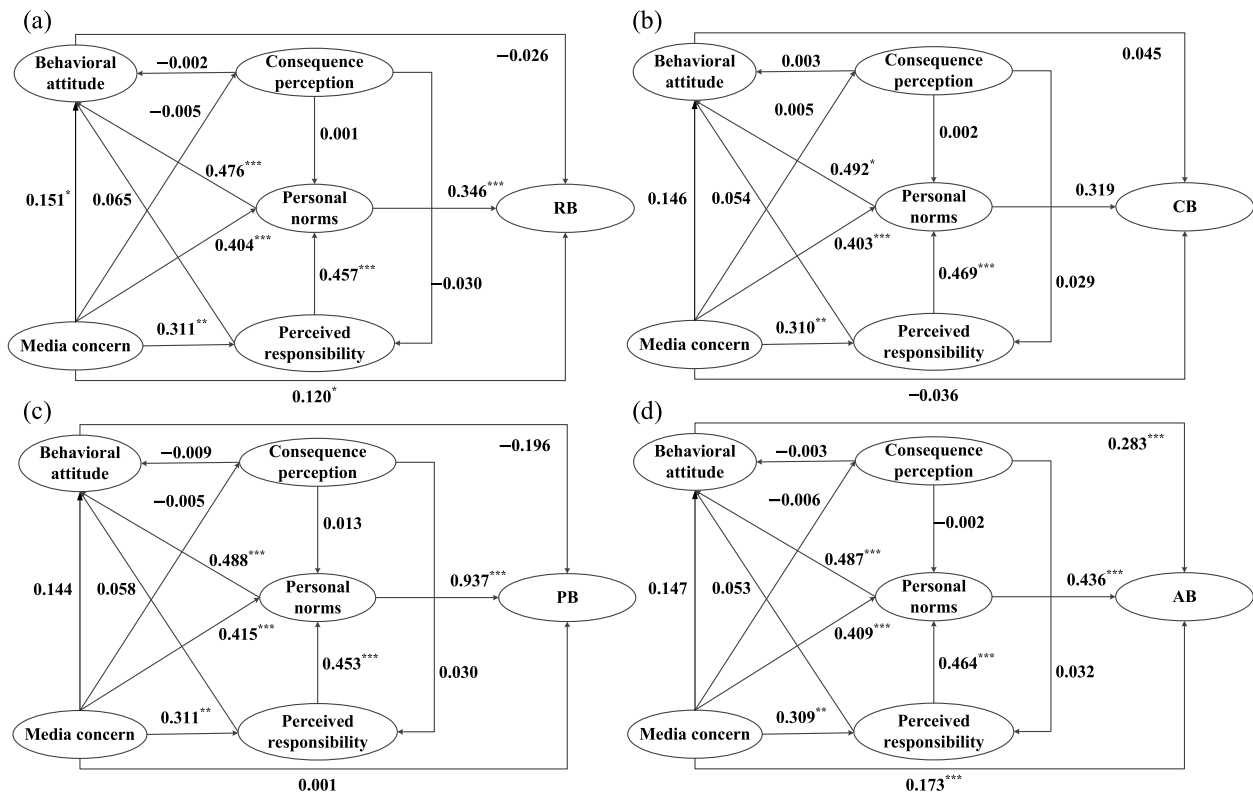
Fig. 4 Standardized estimates of four PEBs in marine environmental protection. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Finally, the role of media concern was examined. The empirical findings did not reveal a direct influence of media concern on PEBs in marine environmental protection because it was only significantly positive in the recycling behavior model ($\beta_{CB} = 0.120$, $p < 0.10$), and the accommodating behavior model ($\beta_{AB} = 0.173$, $p < 0.05$), and is not validated in the other two behavior models, which is therefore not consistent with H3a. It is worth noting that media concern had a significantly positive impact on the public's PR ($\beta_{RB} = 0.311$, $\beta_{CB} = 0.310$, $\beta_{PB} = 0.311$, $\beta_{AB} = 0.309$, $p < 0.05$) and PNs ($\beta_{RB} = 0.404$, $\beta_{CB} = 0.403$, $\beta_{PB} = 0.415$, $\beta_{AB} = 0.409$, $p < 0.01$), thereby supporting H3b and H3c. However, the effect of media concern on CP is insignificant, which is inconsistent with H3d.

4.4 Mediation analysis
The theoretical model has many direct effect paths, and also includes various indirect effect channels, e.g., PR has an indirect impact on PEBs by influencing PNs. The mediating effects are analyzed using the bootstrap method, and the main results are displayed in Table 5. In the baseline NAM model, PNs play a significant mediating role in the relationship between PR and all four types of PEBs ($\beta_{RB} = 0.166$, $\beta_{CB} = 0.139$, $\beta_{PB} = 0.367$, $\beta_{AB} = 0.311$,

$p < 0.01$). That is, PR is a key factor in motivating residents' willingness to implement PEBs, which can be translated effectively into concrete marine environmental protection practices by improving PNs. In addition, although CP can affect PNs through PR, this mediating effect path is not significant. In the extended NAM, we first verify whether CP and PR mediated the effects of media concern and behavioral attitude on PNs, and the results show that there are significantly indirect effects. PNs play a significant mediating role in the effect of behavioral attitude on PEBs ($\beta_{RB} = 0.566$, $\beta_{CB} = 0.170$, $\beta_{PB} = 0.515$, $\beta_{AB} = 0.306$, $p < 0.10$). This indicates that respondents who have strong PNs toward marine environmental protection would show a more positive behavioral attitude, which further engages people in implementing PEBs in marine environmental protection. Meanwhile, PNs and behavioral attitudes play an important mediating role in the effect of media attention on PEBs involved in marine environmental protection. This suggests that psychological factors such as behavioral attitude act as mediating mechanisms in the relationship between media concern and the public's willingness to participate in PEBs (Meng et al., 2023). The higher the level of media concern, the more it helps to raise public awareness of marine environmental protection, which, in turn, strengthens PNs,

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Table 5 Mediating effect of the NAM

Independent variable	Mediator	Dependent variable	Value	SE	Mediation confidence interval	
					Lower	Upper
Perceived responsibility	Personal norms	Recycling behaviors	0.166***	0.034	0.117	0.232
Perceived responsibility	Personal norms	Consuming behaviors	0.139***	0.030	0.093	0.193
Perceived responsibility	Personal norms	Public behaviors	0.367***	0.053	0.287	0.466
Perceived responsibility	Personal norms	Accommodating behaviors	0.311***	0.050	0.233	0.399
Personal norms	Behavioral attitude	Recycling behaviors	0.566***	0.097	0.094	0.566
Personal norms	Behavioral attitude	Consuming behaviors	0.170*	0.127	0.055	0.380
Personal norms	Behavioral attitude	Public behaviors	0.515***	0.125	0.284	0.682
Personal norms	Behavioral attitude	Accommodating behaviors	0.306***	0.119	0.300	0.641
Media concern	Personal norms	Recycling behaviors	0.188***	0.048	0.079	0.368
Media concern	Personal norms	Consuming behaviors	0.173***	0.063	0.058	0.343
Media concern	Personal norms	Public behaviors	0.525***	0.052	0.405	0.637
Media concern	Personal norms	Accommodating behaviors	0.300***	0.050	0.182	0.496
Media concern	Behavioral attitude	Recycling behaviors	0.050**	0.032	0.122	0.359
Media concern	Behavioral attitude	Consuming behaviors	0.075**	0.030	0.016	0.139
Media concern	Behavioral attitude	Public behaviors	0.087**	0.036	0.030	0.142
Media concern	Behavioral attitude	Accommodating behaviors	0.202***	0.041	0.069	0.177

SE standard error

* $p < 0.10$

** $p < 0.05$

*** $p < 0.01$

catalyzes positive behavioral attitudes, and demonstrates a greater willingness to implement PEBs.

5 Discussion

The ocean is an open ecosystem, and the protection of the marine environment is inseparable from the environmentally friendly behaviors of the public. Exploring the public's PEBs is conducive to using public power effectively in marine environmental protection. This paper investigates residents' intention to perform four types of PEBs, including eight specific behaviors, and finds that respondents are generally very willing to implement PEBs concerning marine environmental protection and to participate in all four categories of PEBs above 85%. Among them, residents display the most positive attitudes toward RBs. The survey also shows that 83% of the respondents agree that PEBs are useful and effective for protecting the marine ecological environment. This suggests that there is already a public basis for realizing the common participation of all people in environmental management to a certain extent. Therefore, it is necessary to further explore the influencing factors of the public's PEBs to better guide them to participate in marine environmental protection and achieve universal governance of ecological problems. Our research framework extends the NAM model by adding behavioral attitude and media

concern into the traditional NAM analytical framework to enhance the model's explanatory power for PEBs in marine environmental protection and to propose a model that predicts the public's PEBs, which, in turn, can help the government come to a scientific decision on marine environmental protection.

In this paper, the NAM is used to analyze the determinants of individuals' PEBs, and it is more effective in explaining public-sphere behaviors and accommodating behaviors than in exploring private-sphere behaviors. This may be because there are many self-interested motivations at play when residents decide whether to carry out private-sphere behaviors; however, residents show many altruistic motivations in carrying out public-sphere behaviors and accommodating behaviors. It also shows that, to some extent, the NAM does not take self-interested motivations into account and thus explains the public-sphere behaviors and accommodating behaviors effectively but is not very applicable to the exploration of private-sphere behaviors. Additionally, the original version of the NAM proposes a linear model, which posits that CP activates PNs via PR (Liere & Dunlap, 2010). It also shows a linear progression from CP to PR to PNs to PEBs. PNs are considered to be the direct determinants of environmentally friendly behaviors and intentions in some studies (Zhang et al., 2017). This paper also reveals

the substantial effect of PNs on PEBs, thereby supporting earlier research. Additionally, PNs have the strongest impact on PBs, followed by accommodating behaviors, RBs, and CBs. This may be because PNs are internalized norms and, as such, express individual altruistic motivations, thus showing a stronger effect on PBs and accommodating behaviors than on RBs and CBs. At the same time, the public's PR is found to be closely related to PNs (Kim et al., 2022; Wu et al., 2022), i.e., the stronger the PR is, the more likely it is that PNs will be reinforced. The previous research suggests that the relationship between CP and PR is consistently linear (Liere & Dunlap, 2010). However, this relationship is not significant in this study. This may be because most people have a strong PR to protect the marine environment, whether residents hold a strong CP or not. Therefore, people who are more sensitive to CP cannot perceive a significantly higher responsibility than those with low CP.

Additionally, behavioral attitudes and media concerns are included to extend the NAM. The model's ability to explain all four types of PEBs is generally strengthened. By analyzing the influence pathways in the extended model, this paper reveals that behavioral attitude only has a direct and positive effect on accommodating behaviors and does not show a significant effect on the other three types of PEBs. This suggests that people with strong behavioral attitudes are more willing to demonstrate their willingness to participate in PEBs through indirect behaviors (e.g., showing their interest in marine conservation information) than through direct participation in actual marine environmental protection. This indicates that the problem of 'high awareness and low action' still exists in environmental governance in China. Moreover, behavioral attitudes are also positively influenced by PR. People with a strong PR for environmental damage have a positive behavioral attitude toward implementing PEBs in marine environmental protection.

Furthermore, media concern, which is a public engagement channel (Sipilä et al., 2024), has been found to have a significantly positive correlation with environmental protection behaviors in many areas (Adams & Gynnild, 2013; Ho et al., 2014). While some studies have shown that increased media concern is not enough to encourage the public to develop actual PEBs (Whitmarsh & O'Neill, 2010), these findings should not overshadow the positive role of media concern in promoting PEBs. Some studies even point out that direct media concern has a negative effect on public PEBs (Ming et al., 2022), which is uncommon and should not be seen as a dominant factor in media concern's effect on relationships with PEBs (Liu et al., 2021). The varying findings of existing studies highlight the need for further research to understand the complexity of this relationship, but overall, the positive correlation between media attention and PEBs is clear and influenced by different cultural characteristics, research contexts, and survey samples. This paper shows that media concern does not have a significantly direct effect on accommodating behaviors, but not on the other three major behaviors. This indicates that a high level of attention to environmental information would increase residents' behaviors to further search for related information and discuss the problem with others but it is difficult to directly stimulate actual behaviors to protect the environment. However, the role of media concern in environmental governance still should not be ignored. Media concern, which is an important channel for providing comprehensive information to the public (Xu et al., 2024a, 2024b), is found to have an indirect and positive effect on PEBs through PNs and PR (Liu & Li, 2021). It may be because environment-related knowledge of the public may be amplified with increased media concern. That is, media information transmission would be successful in activating PNs and PR for the promotion of PEBs by increasing environmental knowledge, resulting in residents' improved willingness to implement environmentally friendly behaviors in marine environmental protection (Han et al., 2021).

6 Conclusions, implications, and limitations
6.1 Conclusions
Public participation is an important force in marine environmental protection. We investigated eight specific behaviors of the public to understand the general situation of PEBs in marine environmental protection and extend the existing NAM by introducing media concerns and behavioral attitudes to analyze the formation mechanism of PEBs. This provides an important basis for taking effective measures to achieve scientific decision-making on marine environmental protection. The eight specific behaviors are divided into four types of PEBs, and the results show that respondents generally show a high intention to implement all types of PEBs in relation to marine environmental protection. However, there are many differences between individuals' preferences toward behaviors. Specifically, residents express the most positive attitudes toward RBs, followed by accommodating behaviors, PBs, and CBs. Furthermore, the NAM shows much stronger explanatory power in understanding accommodating behaviors and PBs than in exploring CBs and RBs. PNs can impact PEBs directly, and PR and media concerns have an indirect impact on PEBs. Meanwhile, differences exist in the formation mechanisms of different behaviors. Both behavioral attitudes and media concerns are significantly and positively correlated with

accommodating behaviors, while there is no significant effect on the other three types of PEBs.

6.2 Policy implications

From a practical perspective, this study explores the public's PEBs in marine environmental protection based on the extended NAM, which has an important reference value for achieving scientific decision-making on marine environmental protection. Previous studies have shown that marine environmental protection is not the sole responsibility of the government, and public participation is considered to have an important role in strengthening marine environmental governance. Therefore, the government should implement policies that canvass a wide range of public opinion and implement policies to increase public enthusiasm for participating in PEBs. Combined with the results of this paper, we believe that the government can construct a mechanism to boost public participation in marine environmental protection in China from the two aspects of pushing power and pulling power, as shown in Fig. 5.

From the perspective of pushing power, the government can implement strategies and further promote public participation in marine environmental protection. First, the government should coordinate the behavioral preferences of different participants in marine environmental protection and increase the public's willingness to participate in PEBs in marine environmental protection in all aspects. Government authorities should pay more attention to adopting effective measures to stimulate RBs, such as waste recycling policies. However, the other three behaviors should also not be neglected, and they should be synergized to contribute greatly to the scientific effectiveness of policies on marine ecological protection behaviors. Second, the government should improve marine protection laws and regulations to clarify the responsibilities and obligations of individuals. By setting clear guidelines and regulations, individuals can better understand their roles in marine environmental protection, which can help establish a strong foundation for public participation. Third, the government should provide resources and support to help citizens fulfill their responsibilities in marine environmental protection effectively. This can include training in marine conservation education and access to the necessary marine-related tools and information.

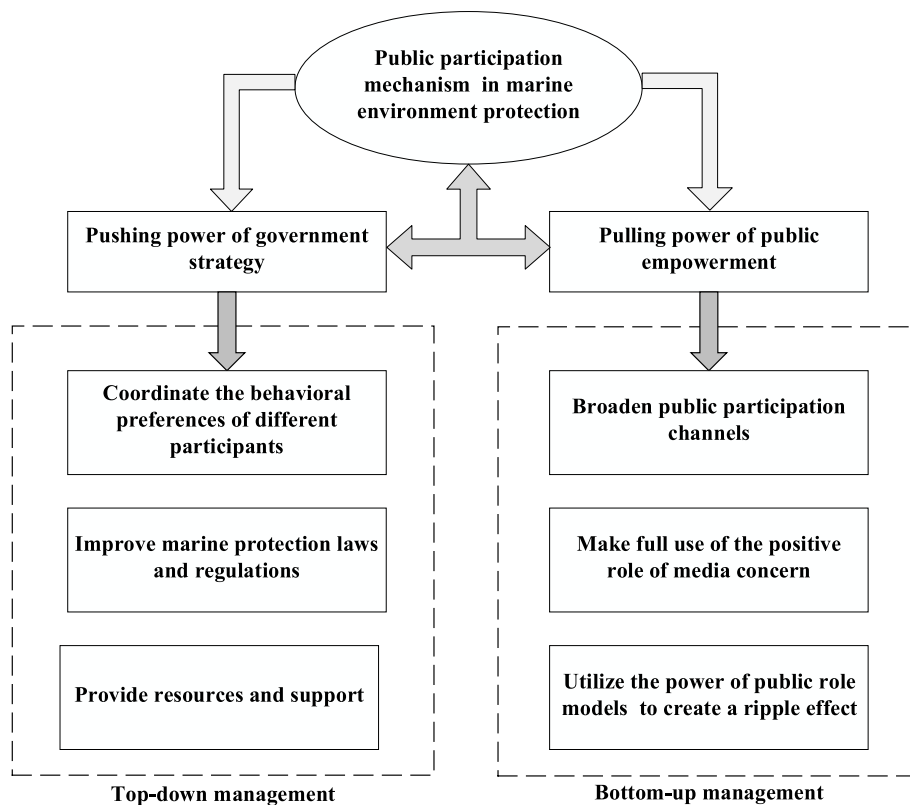From a bottom-up management perspective, the government can empower the public and further

Fig. 5 Construction of the public participation mechanism in marine environmental protection

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increase the public's willingness to implement PEBs concerning marine environmental protection. First, governments should broaden public participation channels, e.g., community clean-up events, awareness campaigns, and public hearings. Involving the public in decision-making processes and fostering a sense of ownership can strengthen PNs and further increase the willingness to participate in PEBs in marine environmental protection. Second, the government could make full use of the positive role of media concern, e.g., posting videos on online platforms about marine environmental degradation, alerting the public to the human-induced causes and activating positive PNs, enhancing PR, and further cultivating a positive social ethos for marine environmental protection. Finally, the government can harness the power of public role models to create a ripple effect. By regularly recognizing and honoring those individuals who excel in marine environmental protection, the government can inspire other members of the public to participate in PEBs in marine protection.

6.3 Limitations

There are limitations in this study. First, at the theoretical level, the direct effects of CP on PR must be tested further in future studies, and the effects of behavioral attitude need to be further verified. Second, this paper only investigated eight specific PEBs of the public in marine environmental protection; however, there is a great deal of variation between different PEBs. It is necessary to construct a special model for each type of PEB. Finally, there are significant differences in the economic development and marine environment of different coastal areas in China, and the differences and similarities between different areas of the country need to be further researched.

Authors' contributions
All authors contributed to the study conception and design. The first draft of the manuscript was written by Yue Lin. Review and editing were conducted by Zhihua Xu and Shuqin Li. Material preparation, data collection, and analysis were performed by Yiming Huang and Shuqin Li. All authors commented on previous versions of the manuscript. All authors had read and approved the final manuscript.

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