Assessing Social-Ecological Fit of International Marine Agreements and Marine Product Trade Flow Networks

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1. Introduction

The marine product trade (MPT) plays a complex dual role in the interaction between humans and the oceans. MPT is not only about economic trade flows, but also about ecological sustainability, social well-being, cultural preservation, and other factors. MPT has supported global economic development and has had a profound impact on marine ecosystems. However, in some underdeveloped countries, especially Small Island Developing States (SIDS), seafood is not only the main source of protein, but also the main source of income for populations highly dependent on marine resources. From an ecosystem perspective, the MPT has also given rise to a series of ecological problems. The large-scale flow of marine ecological products, especially the problem of excessive and illegal fishing driven by economic interests, is likely to pose serious challenges to the quality of marine habitats and the carrying capacity of the ecosystems of underdeveloped countries. These challenges may ultimately result in the loss of the services of marine ecosystems. For this group of countries, the MPT may have a non-equitable distribution. The underdeveloped countries, which bear the brunt of the ecological and environmental risks associated with the MPT, may not be adequately protected by the International Maritime Environmental Agreements (IMEASs) to which they are entitled. There is a significant discrepancy between the MPT and the IMEASs, which is manifested in a mismatch between the two. This mismatch problem is a social-ecological system (SES) mismatch with social, economic, and environmental implications.

To address these issues, we consider MPTs as an ecological network and IMEAS as a social network. We utilized the complete IMEAS relationship network data and global MPTs data among 189 countries or regions from 1995 to 2022 to transform the raw data into a bimodal socio-ecological network through data processing methods such as code conversion and objective assignment. The suitability of the socio-ecological matching network was evaluated using the quadratic assignment procedure (QAP) correlation method.

2. Framework & Methods

2.1 Framework

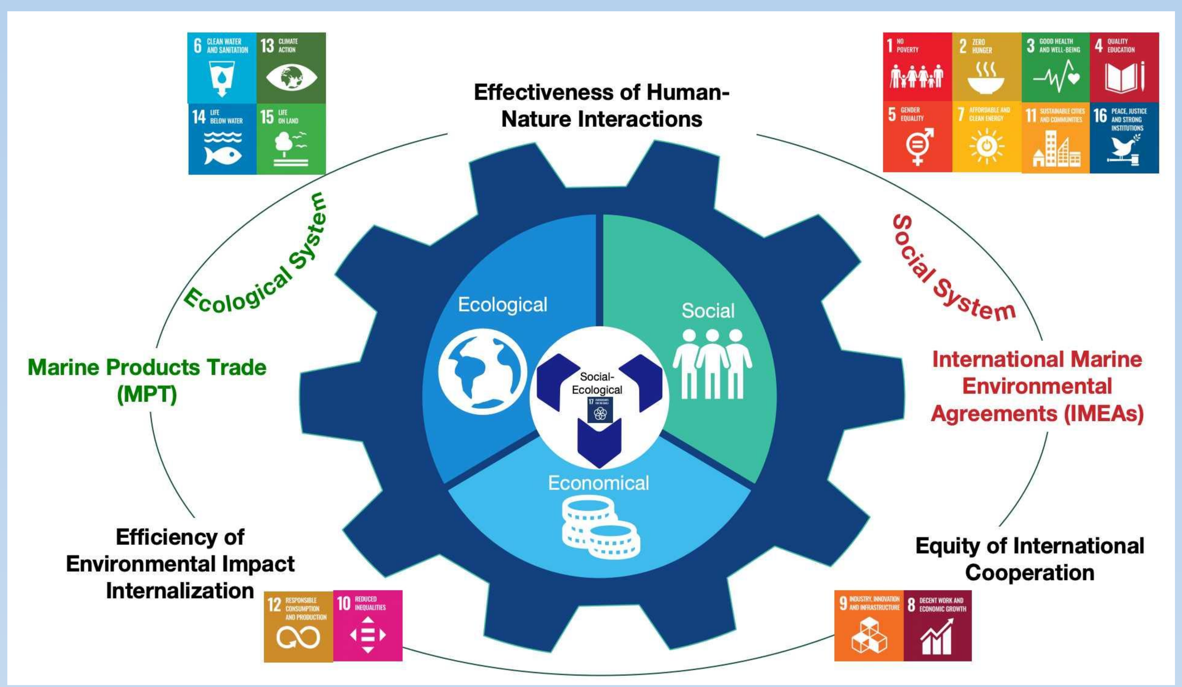

Fig.1 Significance of social-ecological fit of MPT and IMEAs

Based on the socio-ecological-economic division of the SDGs (Rockström & Sukhdev, 2016) and an interdisciplinary perspective, the significance of socio-ecological matching of MPT and IMEAs can be further summarized as follows: the efficiency of the internalization of environmental impacts, the fairness of international cooperation, and the effectiveness of the interaction between humans and nature. The analytical framework allows for a deeper understanding of the socio-ecological matching effects of MPT and IMEAs.

2.2 Data

IMEAs were designated as social system data. In order to identify relevant data, we conducted a preliminary screening of the International Environmental Agreements (IEA) database constructed by Mitchell et al. (2020). This screening was conducted with a focus on data pertaining to MARINE and OCEAN. The raw data consist of the behavior of countries or regions to ratify or participate in the agreement, expressed in the form of a bimodal network of country/region agreements. In order to account for the lag effect of the agreement, the time scale of the data selected is set to 1995-2022. In order to identify the number of countries or regions that have ratified agreements in a given year, we have coded the data as follows: if a country or region has ratified an agreement in the current year and in the previous year, we have coded this as 1. Conversely, if a country or region has not signed or launched an agreement, we have coded this as 0. Finally, we have summed up the coded values to represent the number of common agreements in which countries or regions participate. This can be regarded as a sign of social bonding.

For the ecological data, we selected MPTs data from 1995 to 2022. This data is derived from the United Nations Commodity Trade (COMTRADE) statistics and contains detailed bilateral import and export statistics through CEPII's BACI database (Gaulier et al., 2020). The raw bilateral trade flow data were assigned HS92 codes and converted to SITC 3 codes using the UNSD correspondence tables.

2.3 Methods

The QAP method is a widely utilized approach in social-ecological systems research for evaluating the compatibility between two matrices. Intuitively driven by the concept of Pearson's correlation coefficient (Hanneman & Riddle, 2005), the product-moment graph correlation between labeled social and ecological graphs S and E is given by:

$$\mathrm{cor}(S,E) = \frac{\mathrm{cov}(S,E)}{\sqrt{\mathrm{cov}(S,S)\mathrm{cov}(E,E)}} \qquad (1)$$

Where the graph covariance is defined as $\mathrm{cov}(S,E) = \frac{1}{\binom{|V|}{2}} \sum_{\{i,j\}} (A_{ij}^S - \mu_S)(A_{ij}^E - \mu_E)$, with A^S being the adjacency matrix of G_S (Butts & Carley, 2001; Krackardt, 1987). After the product-moment correlation is obtained, Quadratic Assignment Procedure tests an arbitrary graph-level statistic (in this case, the correlation) against a QAP null hypothesis, via Monte Carlo simulation of likelihood quantiles.

3. Results & Discussion

3.1 Network analysis

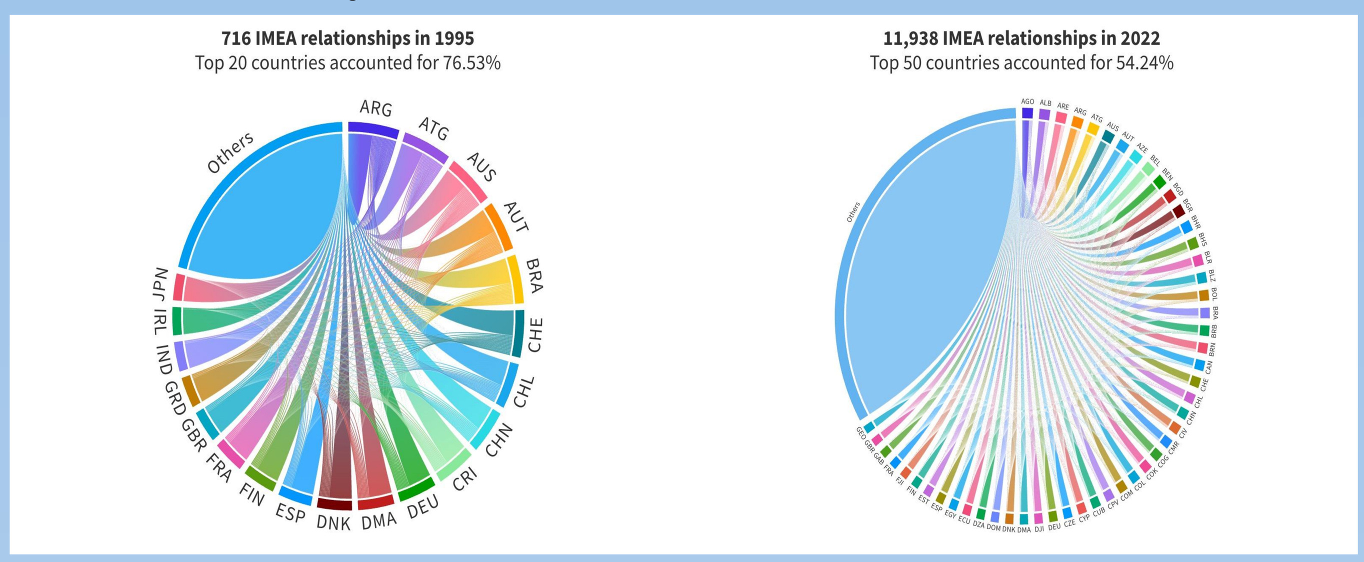

Fig.2 IMEA networks in 1995 (left) and 2022 (right). Country (region) are in the alpha-3 code

As illustrated in Figure 2, the results can be summarized as follows. In 1995, 189 countries or regions collectively generated 716 IMEAs links. By 2022, this figure had increased to 11,938, representing a 16.67-fold increase over 1995 and an average annual growth rate of 10.98%. This demonstrates that as the global community has become more multipolar, economically globalized, and socially informed, it has increasingly attached importance to marine environmental protection and the sustainable development of the oceans. This has led to the advancement of global marine environmental governance, which is conducive to the realization of the goal of sustainable development.

Secondly, among the top 20 countries or regions, it accounts for 76.53% of the total IMEAs relations. By 2022, the top 50 countries or regions accounted for only 54.24% of these linkages. The distribution of IMEAs linkages among countries and regions is more balanced and less concentrated. Nevertheless, developed countries, such as the United States, Canada, Australia, and the United Kingdom, continue to exert a dominant influence on IMEAs. Conversely, least developed countries (LDCs) or SIDS, such as Seychelles and Timor-Leste, exhibit comparatively weaker IMEAs linkages. This suggests that there is a non-equality of imbalance of state roles in the global ocean governance system.

3.2 QAP correlation fit

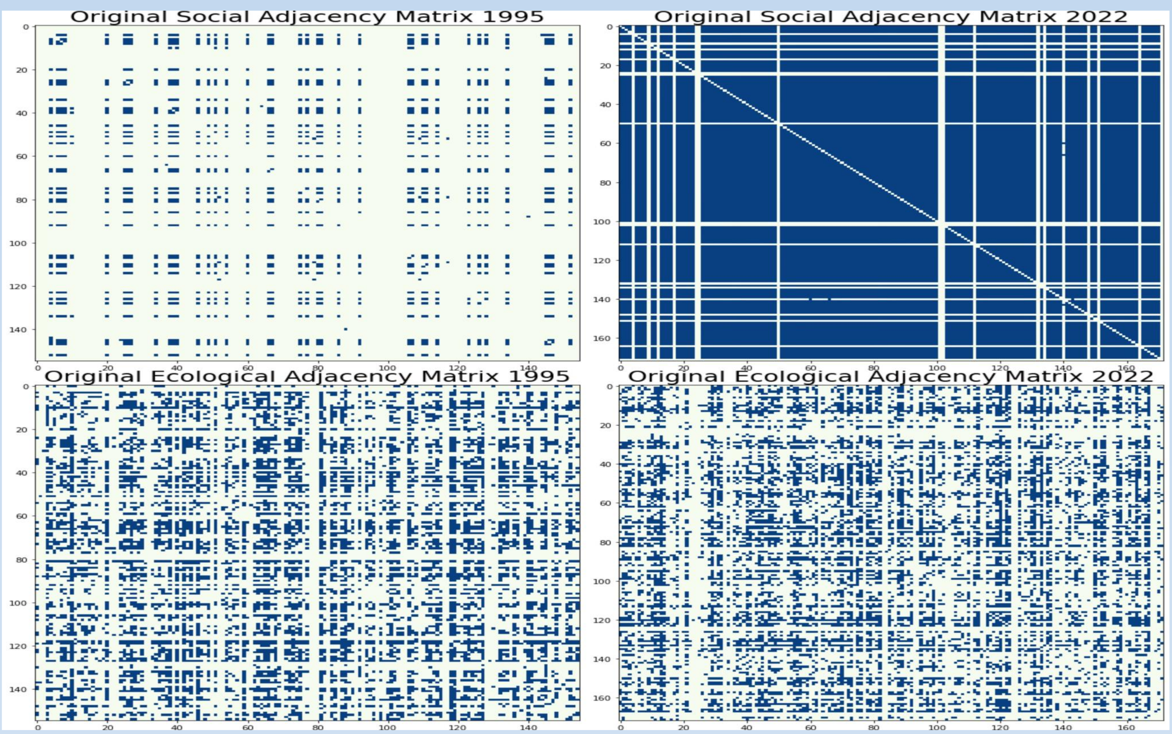

Fig.3 Social and ecological networks forms in 1995 (left) and 2022 (right)

Fig.3 displays product-moment correlation results for social-ecological networks during 1995-2021 in 1000 permutations. The lump of data is generally at the start, exhibiting a right-skewed distribution.

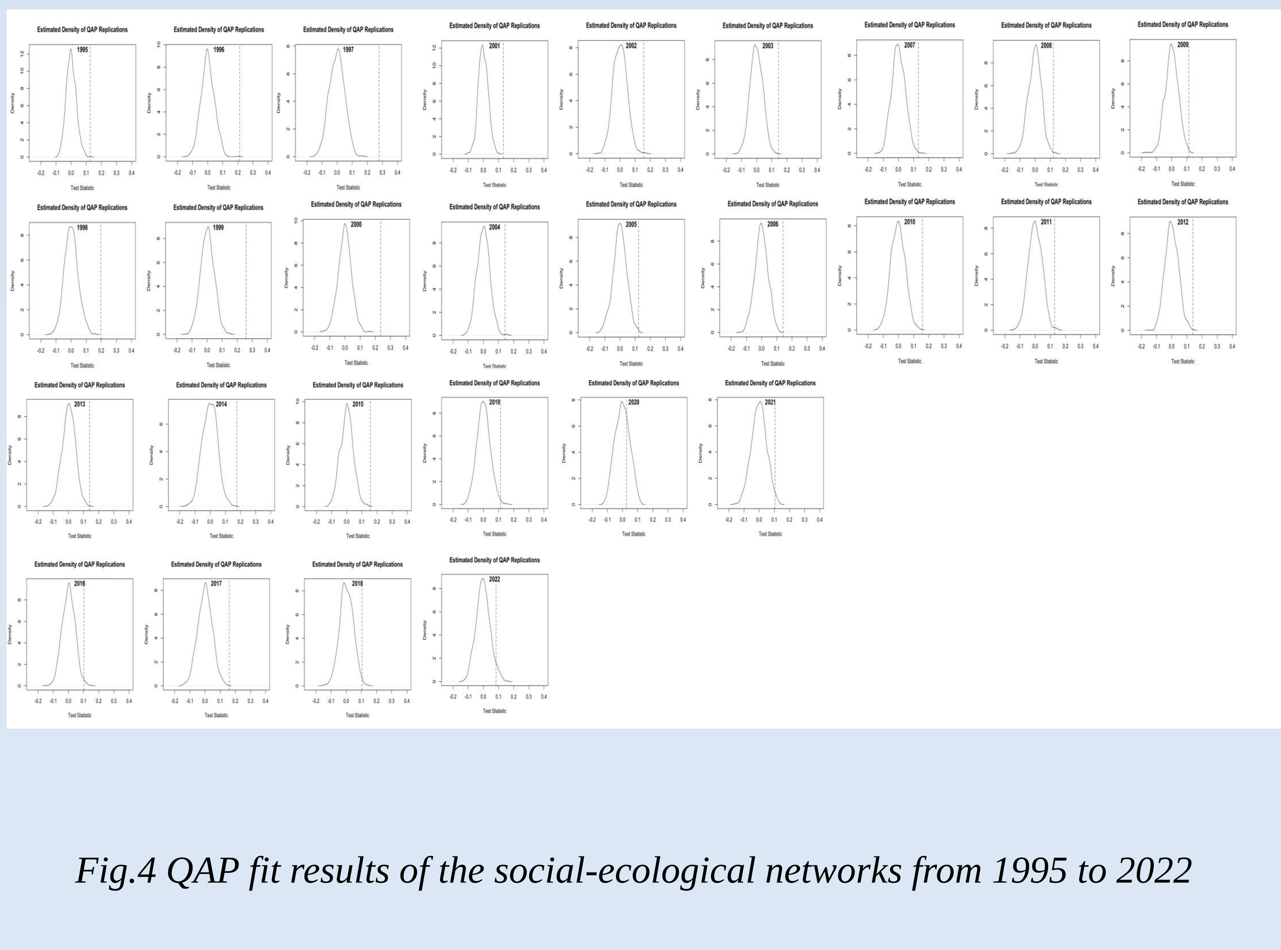

Fig.4 QAP fit results of the social-ecological networks from 1995 to 2022

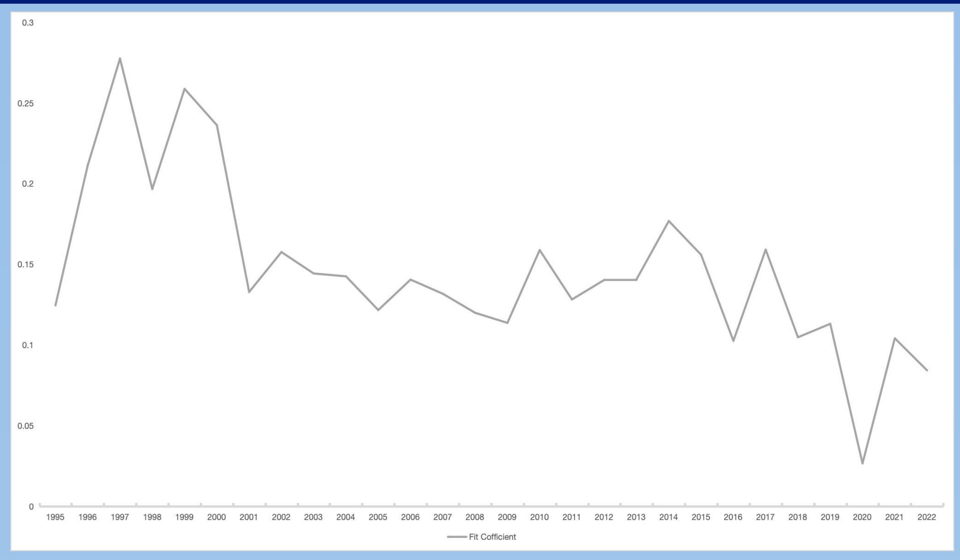

Fig.5 Trends in social-ecological fit

Figure 4,5 illustrates a longitudinal comparison between fit values at each time point, which reveals a downward trend over the past 28 years. The mean social-ecological system match was 0.1466, with a confidence interval of $p < 0.001$. In summary, we employed the QAP correlation method to examine the socio-ecological networks of IMEAs and MPTs. Our longitudinal comparisons revealed a downward trend in the socio-ecological match between IMEAs and MPTs over the past 28 years, as well as a weakening of the influence of ecological networks on social networks. We posit that this may be attributed to a number of factors.

1.A discrepancy between policies and actual needs may result from the inability of IMEAs to adapt to or reflect the development and needs of actual MPTs. This may lead to limitations in the effectiveness of policies. The development of global policies by developed countries that fail to consider contextual non-equity issues, such as differences between countries, and procedural non-equity issues, such as the failure to consider the interests of underdeveloped countries and SIDS, may lead to such a disconnect.

2. An increase in MPTs may lead to overexploitation of marine resources, such as the loss of marine biodiversity in their own countries as a result of overfishing, degradation of the quality of their marine habitats, and other ecological risks. The South is situated in an imbalanced position within the global ocean governance system. These activities are not effectively controlled by existing IMEAs and do not yet reflect the principle of distributive justice. Furthermore, the implementation of IMEAs often requires the cooperation and commitment of governments. In the event that countries are unable to demonstrate sufficient cooperation or exhibit significant differences in implementation, this may result in a decline in the effectiveness of the agreements.

4. Introduction of MCIGI

Research Field

Marine/Coastal Spatial Governance

Marine Conservation Social Sciences

Socio-Oceanography

Overall Academic Contribution

1. Constructing a transdisciplinary theoretical system of socio oceanography integrating marine natural sciences and social sciences.

2. Systematically propose the dynamic mechanism and hybrid model of marine social-ecological system.

3. Expand and develop the "spatiotemporal social" full-scale method of social-ecological system fit.

4. Develop the framework of "spatiotemporal society" for the sustainable development of social-ecological systems in coastal cities, and propose the method of coupling different elements.

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