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WRGSD: improving reliability and efficiency for coastal monitoring network

Water-quality response grid-based sampling design (WRGSD) using optimization and multi-factors assessment can reliably detect a variety of the impact of human activities. The sampling design are optimized by clustering and dividing the water quality response grid to reduce the number of initial stations and by random sampling to cut down the number of stations with same information. Multi-factors of maritime space coverage, monitoring site coverage and spatial monitoring information agreement are used to assess the reproducibility, and the factors of the degree of marine functional zone sharing, site equilibrium coefficient, and site effectiveness are used to assess the efficiency.

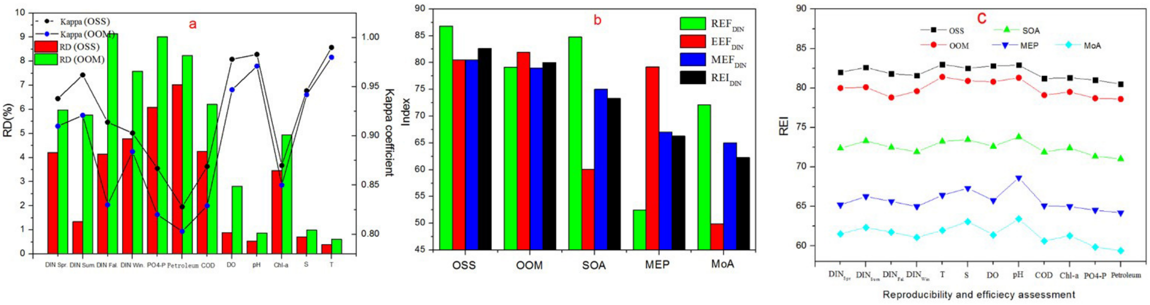

Fig. 1. (a) Applicability evaluation of dissolved inorganic nitrogen (DIN) in spring, summer, fall, and winter and factors of dissolved oxygen (DO), pH, chemical oxygen demand (COD), phosphorus (PO4-P), petroleum, temperature (T), salinity (S), and Chlorophyll-a (Chl-a) in summer for the RD ≤ 1% and RD ≤ 5% optimized monitoring site networks, (b) assessment of the reproducibility and efficiency index (REI), the reproducibility evaluation factor (REF), the efficiency evaluation factor (EEF), and the land-sea spatial matching evaluation factor (MEF) of DIN in spring, summer, fall, and winter, (c) assessment of the reproducibility and efficiency index (REI) of DIN in spring, summer, fall, and winter and factors of DO, pH, COD, PO4-P, petroleum, T, S, and Chl-a in summer. Where, OSS and OOM represent the optimized special surveys stations and the optimized operational monitoring stations, and SOA, MEP, and MoA represent the State Oceanic Administration, the Ministry of Environmental Protection and the Ministry of Agriculture respectively.

WRGSD includes 5 steps: (I) selects environmental reference factors, which are the most representative factor that can reflect the spatiotemporal distribution and the variation regularity of various factors in target area; (II) divides the sampling grid, i.e. water quality response grid, which can be calculated using a three-dimensional biogeochemical–hydrodynamic model by linking the land-based load with water quality; (III) sets the initial stations, which include hydrodynamic and biogeochemical stations, consisted of stations in mixed boundary, outer boundary, and central locations of the sampling grid; (IV) optimizes the sampling stations, by using the random inspection method with Matlab software based on deviations (relative deviation, and Cohen's Kappa coefficient) to reduce the number of initial stations in the interpolation of initial stations of the full maritime grid; (V) assesses the proposed network's reproducibility and efficiency (reproducibility and efficiency index, REI), which is calculated as the average value of three factors: the reproducibility of site layout (reproducibility evaluation factor, REF), the effectiveness of site layout (efficiency evaluation factor, EEF), and the land-sea spatial matching degree (land-sea spatial matching evaluation factor, MEF).

The monitoring networks proposed in the Bohai Sea have 225 stations for optimized special surveys (OSS) and 181 stations for optimized operational monitoring (OOM), accounting for 46.5% and 37.4% of the original station totals, respectively. The reproducibility and efficiency analyses of the OSS and OOM stations based on dissolved inorganic nitrogen (DIN) and other factors of dissolved oxygen (DO), pH, chemical oxygen demand (COD), phosphorus (PO_4-P), petroleum, temperature (T), salinity (S), and Chlorophyll-a (Chl-a) are consistent with the interpolated results across the whole grid in all seasons of 2016 (Fig. 1a). The three highest REF values belonge to OSS, the State Oceanic Administration (SOA), and OOM, which are significantly higher than the Ministry of Environmental Protection (MEP) and the Ministry of Agriculture (MoA) ($P < 0.05$). The three highest EEF values belong to OOM, OSS, and MEP, which are significantly higher than SOA and MoA ($P < 0.05$). The two highest MEF values belong to OOM and OSS, which are significantly higher than SOA, MEP, and MoA ($P < 0.05$) (Fig. 1b). The REIs for the OSS and OOM are 81.9%±0.8% and 80.1%±0.9%, respectively, higher than SOA, MEP, and MoA (Fig. 1c). Therefore, the OOM and OSS stations are the most reproducibility and efficient at land-sea matching and can be used as the optimized layout for investigative and operational monitoring stations.

In contrast, the WRGSD approach proposed in this study can reflect the amount of terrestrially sourced pollutants discharged into the sea and the influence of terrestrial human activities such as large-scale reclamation while quite precisely and efficiently demonstrating the spatiotemporal distribution of offshore pollutant concentrations. The mixed boundary stations proposed in this study can reveal terrestrial influences on coastal water quality and associate these with load contributions defined by authorities. These abilities make it especially suitable for water quality assessment, environmental inspection, and management of severely polluted offshore areas.

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