Mind the Gap: A critical 40-fold workforce shortfall for protecting 30% of the ocean

Running head: Global MPA workforce assessment

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Summary statement

Despite being among the world's most important workforces, responsible for protecting life and livelihoods worldwide, the global marine protected area workforce is critically insufficient—approximately 90,000 people globally—requiring a ~2-fold increase to deliver intended conservation outcomes today and a workforce of 3.7 million to achieve the goal of protecting 30% of the ocean.

Abstract

Despite being tasked with protecting ocean biodiversity, the marine protected area (MPA) workforce remains poorly described. Using a global site-level questionnaire, we assessed staffing, workforce adequacy, technology use, and personnel requirements for effectively and equitably conserving 30% of the ocean by 2030 (30×30). Responses represented 52.8% of global MPA area across 63 countries and territories. Staffing was consistently low—averaging one worker per 412 km²—ten times fewer than in terrestrial protected areas. One fifth of MPAs had fewer than one full-time equivalent and two thirds had fewer than ten. Staffing was higher in fully/highly protected and Blue Park sites. Technology was used where staffing was ample, amplifying rather than replacing workforce. Achieving 30×30 requires expanding the workforce from ~90,000 to 3.7 million people—with non-staff actors present near most MPAs (97%), mobilizing this latent workforce may provide a scalable pathway for protecting and reviving the ocean.

Keywords: Marine Protected Areas, Ocean, Conservation, 30×30, Governance, Blue Economy

Introduction

Over the past 150 years, pervasive and accelerating misuse of the Earth's ecosystems has eroded their capacity to sustain biodiversity, regulate climate, provide food and livelihoods, and support human well-being—threatening long-term prosperity (Aburto-Oropeza et al. 2025; Costanza et al. 2014; Pörtner et al. 2021; Reid et al. 2005). Recognising that area-based conservation is part of the solution, science, policy, investment, and civil society have, under Target 3 of Kunming-Montreal Global Biodiversity Framework, converged around a near-term goal of conserving at least 30% of the world's lands and seas and fresh waters within protected and conserved areas by 2030 (aka "30×30"; Secretariat of the Convention on Biological Diversity 2024; Brouder 2010; Rodrigues et al. 2006; World Bank 2019). While careful design and placement of protected and conserved areas is important (Watson et al. 2014; Coad et al. 2019; Geldmann et al. 2013), achieving conservation outcomes ultimately depends on skilled, adequately resourced site-based people working to implement management and adaptive decision-making aligned with protected area objectives (Grorud-Colvert et al. 2014, 2021; Bruner et al. 2001; Graham et al. 2021; Gill et al. 2017).

A recent global assessment of terrestrial protected areas identified severe workforce shortfalls, estimating ~555,000 personnel worldwide (one per 37 km²)—far below recommended levels (one per 13 km²)—and projecting that achieving the 30×30 target requires expansion to roughly 3 million personnel (Appleton et al. 2022). The ocean, however, presents fundamentally different conditions that limit the direct transferability of terrestrial workforce estimates and strategies. Marine protected areas (MPAs) face many threats similar to those on land, such as poaching, unauthorized activities, invasive species, and climate-driven warming (Giakoumi et al. 2019; Nunes et al. 2023; Bruno et al. 2018; Brown et al. 2018), but also additional pressures affecting aquatic ecosystems (e.g., acidification, derelict fishing gear and marine debris; Nissen et al. 2024; Doney et al. 2009). Unlike terrestrial protected areas, MPAs include multiple discontinuous zones. They span coastal, offshore and transnational territorial areas with complex jurisdictions and governance structures. They remain largely submerged and beyond direct observation. They are also challenging to access, making it difficult to intercept threats on site (ProtectedPlanet.net, MPAtlas.org). Moreover, protecting 30% of the ocean entails managing more than twice the area of protecting 30% of land (~45 million km² versus ~120 million km²)—Rechberger et al. (2025) found that 30 % protection of territorial seas alone will require protecting an additional 1.68 million km^2 (~190,000 coastal MPAs at an average size of 10 km^2). Together, these differences underscore the need for a dedicated assessment of MPA workforce capacity.

We conceived this study as the marine counterpart to the terrestrial protected area workforce study (Appleton et al. 2022), adapting the approach to reflect the unique spatial, governance, and operational realities of MPAs. Consequently, rather than conducting a country-level assessment, we adopted a site-based approach. We developed and deployed a global questionnaire consisting of four core components: (i) staffing numbers and functional roles (including partial Full-Time Equivalents, FTEs); (ii) technologies used to support management and operations; (iii) the presence of other actors and activities operating within or near the MPA; and (iv) respondent perceptions of workforce adequacy across the reported site(s) (Table A1). To reflect shared staffing arrangements common in marine contexts, respondents could pool responses across multiple MPAs. Together, these data provide the first global, site-level characterization of the MPA workforce, enabling assessment of current staffing, perceived adequacy, and the scale of workforce expansion and budgets required to achieve adequate MPA staffing under existing and future 30×30 scenarios.

We conducted the survey in 2025. The questionnaire was directly linked with the World Database on Protected Areas (WDPA) (via ProtectedPlanet.net) allowing respondents to select, verify, and contextualize the specific MPA(s) to which their responses applied. To achieve global coverage, we implemented a three-phase distribution strategy: (i) broad outreach through professional networks, newsletters, webinars, and social media; (ii) targeted, personalized outreach to all MPA management authorities listed in WDPA (347 initial and 324 follow-up contacts), supplemented by web and academic searches; and (iii) snowball sampling through participant referrals.

To protect sensitive information, no site-identifiable workforce data are reported. Analyses included all responses that identified at least one MPA, with spatial attributes linked to authoritative global databases (WDPA: 2026-01-19, MPAtlas: 2026-03-16). Staffing was quantified in FTEs and analyzed across multiple dimensions, including MPA size, technology used, remoteness, level of protection and stage of establishment (Grorud-Colvert et al. 2021), duration, economic context, and governance setting. We also compared MPAs recognized as Blue Parks with the rest of the dataset, as these sites have been shown to be effectively managed and protected (Marine Conservation Institute 2025). Global workforce numbers for all personnel and in-site-focused personnel (≈ rangers in Appleton et al. 2022) were estimated using a resampling-based extrapolation, drawing empirical workforce numbers from surveyed MPAs and applying them to all MPAs globally. This framework was further extended to estimate workforce requirements for adequate staffing under current MPA extent and projected 30×30 expansion scenarios, providing benchmark estimates.

Results

Sample characteristics

Over a six-month data collection period (April–October 2025), 190 completed questionnaires were submitted by a range of MPA professionals, most commonly in leadership positions (44.2%), with 96.3% of responses rated high or medium confidence in their submitted information about staffing. The responses were associated with 136 independent (i.e. deduplicated) sites linked to spatial records within WDPA or MPAtlas (six additional sites were omitted due to the lack of digitized boundary polygons or points). Sampled sites captured a large and diverse subset of the global MPA area (Fig. 1a), collectively represented 52.8% (18,871,437 km^2 after resolving overlaps) of total global MPA area (here estimated at 35,766,185 km^2), or 42.6% (15,225,974 km^2) when restricted to the 171 single-site responses. Most sites were classified as marine (75.4%), yet the sampling captured a wide range of spatial contexts (coastal, offshore, continental, overseas, shallow, and deep). Responses spanned 63 countries or territories (distinct ISO3 codes), governed by 49 nations (46 for single sites), across the Global North and Global South, with all continents represented except Antarctica (Fig. 1b). Our sampling included very large sites, up to >4,500,000 km^2, but also many small ones (19 sites below <10 km^2; median = 476 km^2, mean = 126,234 km^2, sd = 479,424 km^2, N_{sites} = 136). Responses encompassed sites with diverse governance arrangements, designation, designation types, IUCN Protected Area categories, no-take categories (Fig. 2a–e). All but one sampled site were formally designated, and half had been so since 2007 (Fig. S1). For the 79 sampled sites evaluated by the MPAtlas, the large majority were assessed as actively managed or implemented (N_{sites} = 65) (Fig. 2f).

Workforce size & composition

A total of 4,928 full time equivalents (FTEs) were reported in single-site responses with confident staffing estimation (N_{resp} = 166, N_{sites} = 138, FTEs averaged across replicated sites), corresponding to a mean of 35.7 FTEs per site. After excluding the Great Barrier Reef (MPA ID 2628) which represents an uniquely large well staffed site, the mean dropped to 10.3 (total = 1,406), all sampled sites reported fewer than 100 personnel, more than two thirds of sites had less than 10 FTEs, fifty percent were below 4.5 FTEs and 20.4% had one FTE or fewer (Fig. 3a). Most staffing was near zero—all functional roles had a modal rounded number of FTEs of zero except for leadership at one FTE (Fig. 3b–c): 73.2% of sites ≤ 1.0 FTE for leadership, 60.1% for in-site-focused functions, 73.9% for support, 81.9% for stakeholder, 78.3% for science, and 87.7% for all other roles combined (N_{sites} = 138).

Workforce trends across MPA characteristics

The total number of FTEs showed no systematic relationship with most external MPA characteristics (Fig. S2, Table S1), including the size of the MPA (log-log Linear Mixed-effects Model: $\beta = 0.073$, chi^2 LR = 3.9, df = 1, p = 0.055, $N_{resp} = 160$, $N_{sites} = 132$). The only external MPA characteristics identified as strongly connected to staffing level was the continent where the sites were located (LMM: chi^2 LR = 18.5, df = 5, p = 0.0080, $N_{resp} = 166$, $N_{sites} = 138$), with Africa and Oceania having the highest numbers of FTEs per site on average, and Latin America and the Caribbean being the least staffed (Fig. S3). Several characteristics related to the management of the MPA were also significant. Actively managed or implemented MPAs were more staffed than designated (but not yet implemented), proposed or unknown-status sites (log-identity LMM: chi^2 LR = 12.2, df = 1, p = 0.0080, $N_{resp} = 166$, $N_{sites} = 138$) (Fig. 4a). The protection level was also related to the number of personnel (Fig. 4b), with fully or highly protected sites significantly more staffed (log-identity LMM: $\beta = 1.06$, chi^2 LR = 13.1, df = 1, $p < 0.001$, $N_{resp} = 166$, $N_{sites} = 138$). Within the subset of fully or highly protected MPAs, those awarded as Blue Park tended to have more staff (log-identity LMM: $\beta = 0.81$, chi^2 LR = 4.14, df = 1, p = 0.055, $N_{resp} = 72$, $N_{sites} = 56$) with a median FTE of 18 (mean = 20.1, $N_{sites} = 15$). Staffing was also positively associated with the number of deployed technologies—satellite, radar, drone, underwater acoustic technology, MPA evaluation technology, and reporting tools—(log-identity LMM: chi^2 LR = 50.5, df = 6, $p < 0.001$, $N_{resp} = 166$, $N_{sites} = 138$; Fig. 4c). The number of FTEs increased on average by 1.73 with each additional technology (log-identity LMM: $\beta = 0.24$, chi^2 LR = 44.1, df = 1, $p < 0.001$). Various sites deployed several technologies, but high numbers of technologies were mostly found in large MPAs connected to relatively wealthy governing countries (Fig. S4).

Self-reported staffing adequacy

All but 34 filled-in questionnaires contained information on staffing adequacy (Fig. 5a). Only 4.2% reported it as fully adequate (8 out of 156). Modelling the probability for adequacy to reach at least a certain level of adequacy revealed that this probability increased significantly with the number of reported FTEs within the same site (Fig. 5b, Table S2). At 20 FTEs (Blue Parks average in sample), this translates into probabilities of adequacy of to be at least somewhat adequate of 95.0% ($CI_{95\%}$ = 88.6–97.9%), at least moderately adequate of 77.1% ($CI_{95\%}$ = 64.7–86.0%), and at least mostly adequate of 25.0% ($CI_{95\%}$ = 16.2–36.7%). Again, this result was not significantly impacted by differences in MPA size (Table S3).

Operators present at sites

For all but 18 independent sites, we obtained information on non-staff actors operating within or near MPAs. Operators were reported in 122 out of the 126 retained sites (i.e. 96.8%). Fishers, boat operators and divers were present in most sites (Fig. 6). Respondents providing details about operators not pre-listed in our surveys also mentioned a variety of additional actors, including tourists, naturalists, researchers, and militaries, people using small motorized or non-motorized recreational watercraft (personal watercraft, catamarans, kayaks and other canoes), as well as swimmers and kite surfers.

Global MPA workforce capacity, densities, and expansion scenarios

Given the lack of strong relationships between external drivers and MPA staffing, and the limited sampling (42.6% of the total area of global MPAs, but only 1.68% in numbers of independent sites), we opted for a different approach to predict global workforce in MPAs than that used for terrestrial PAs (Appleton et al. 2022). We relied on a resampling-based extrapolation technique which is dependent on three inputs: (i) the empirical distribution of FTEs in the sample made by single independent sites with confident FTE estimation after discarding the Great Barrier Reef (MPA ID 2628) outlier (N_{sites} = 137), (ii) the estimation of the total number of single independent sites on the planet (N_{sites} = 8,456, corresponding to 16,597 unique MPA IDs from WDPA), and (iii) the assumed proportion of sites with no workforce at all (hereafter unstaffed sites). Considering the proportion of unstaffed sites we observed in our data (9 out of 137, or 6.6%) as a conservative choice, we estimated a total current MPA workforce of roughly 90,000 FTEs (mean estimate = 86,737, $CI_{95\%}$ = 84,060–89,410, Table 1). By construction, a resampling procedure precludes the production of FTE numbers per site higher than those sampled. Yet, parametric, and hybrid empirical-parametric alternative approaches relaxing this assumption produced similar numbers (Fig. S4 & S5).

Applying the same approach to in-site-focused personnel only—defined in our survey as "ranger and ranger-like roles working in the MPA, with and without enforcement capabilities" revealed a higher proportion of unstaffed sites (29 out of 137, or 21.2%) and yielded a global current estimate of ~28,000 FTEs (mean estimate = 28,066, $CI_{95\%}$ = 27,052–29,070).

We calculated average staffing density at one FTE per 3,084 km^2 of MPA for all personnel, and one in-site-focused FTE per 20,200 km^2, within the subset of single independent sites with confident FTEs estimation in our sample (N_{resp} = 166, N_{sites} = 138). However, these staffing densities do not reflect the overall densities since the distribution of the MPA sizes we sampled is biased towards large MPAs (even though some very small sites were included). Combining our global workforce estimates to the total area covered by any MPA in the world (35,766,185 km^2, after resolving all overlaps) provides an unbiased density estimate of one FTE per 412 km^2 for all personnel and one FTE per 1,274 km^2 for in-site-focused personnel.

To identify the needs in personnel numbers required to reach adequacy in existing MPAs, we revised the empirical distribution of FTEs used to estimate the global workforce. We used the empirical distribution of FTEs among sampled MPAs currently awarded as Blue Parks for their management effectiveness (N_{sites} = 15). This new baseline suggested 82,955 additional FTEs would be required to effectively manage current MPAs. This corresponds to a nearly doubling of the current workforce so as to reach approximately 170,000 FTEs in total (mean estimate = 169,692, $CI_{95\%}$ = 166,415–172,879), including ~54,000 in-site-focused FTEs (mean estimate = 54,184, $CI_{95\%}$ = 52,582–55,779).

To reach 30% of the marine space covered by MPAs, Rechberger et al. (2025) estimated the need to raise the number of MPAs to ~ 190,000. Considering this, together with the same distribution of FTEs within these future MPAs as currently observed, yields a total requirement close to 2 million total staff (mean estimate = 1,912,300, $CI_{95\%}$ = 1,899,696–1,925,552), including ~620,000 in-site-focused staff (mean estimate = 617,852, $CI_{95\%}$ = 612,791–622,389). Projecting FTEs needed to reach adequate management effectiveness (i.e. staffed as in current Blue parks sampled) nearly doubles these estimates (mean estimate all FTEs = 3,739,034, $CI_{95\%}$ = 3,723,908–3,754,634; mean estimate in-site-focused FTEs = 1,193,869, $CI_{95\%}$ = 1,186,282–1,201,508) and expresses a need for a workforce roughly 40 times as large as the current workforce (Fig. 7).

Discussion

Global MPA workforce is severely limited

We present the first global, site-level assessment of MPA workforce capacity, revealing a substantial global staffing deficit. Based on a dataset covering close to half of global MPA area, we estimate fewer than 100,000 full-time equivalents (FTEs) worldwide, corresponding to approximately one worker for more than 400 km². This aligns with prior regional studies, where most MPAs fall below minimum staffing thresholds and only a small fraction meet recommended operational levels (e.g., Capriati et al. 2026; Edgar et al. 2014; Gill et al. 2017), indicating that low staffing is a systemic global issue rather than a regional anomaly. Workforce adequacy responses further suggest that current staffing remains substantially below levels required for effective operation. In the absence of standardized global benchmarks, adequacy reflects whether managers believe core functions can be delivered in practice (Coad et al. 2019; Gill et al. 2017).

Scaling personnel up to levels observed in effectively managed MPAs (i.e. Blue Parks) suggests that managing MPAs efficiently requires on average ~ 20 FTEs per site (in agreement with Capriati et al. 2026). Based on the large number of MPAs that may be required to achieve 30×30 targets (Rechberger et al. 2025), this translates into ~3.7 million FTEs globally, i.e. a 43-fold increase in workforce capacity. These estimates are not prescriptive targets, but empirically grounded indications of the scale of operational capacity required.

Caveats

Several limitations should be considered when interpreting these findings. Heterogeneity in MPA definitions and underlying data systems required harmonizing sites with overlapping or layered designations, introducing unavoidable structural uncertainty. Inconsistencies, delays, and missing or non-standardized reporting within global databases such as WDPA limit completeness and imply that current datasets may reflect static or outdated attributes rather than contemporary information. Sampling and reporting biases likely skew results toward better-resourced MPAs where staff were available to respond to the survey. Measures of adequacy are self-reported and should therefore be interpreted as comparative indicators rather than independent assessments of performance. The analysis also focuses primarily on site-level staffing and does not fully capture distributed or external workforce contributions from agencies, NGOs, contractors, and volunteers, although this does not alter the central finding that on-site operational capacity remains globally constrained. Similarly, because our estimates exclusively focus on MPAs, and future expansion may include Other Effective Area-based Conservation Measures (OECMS) and other models, the workforce requirements may differ accordingly. Finally, limited empirical evidence on appropriate staffing benchmarks for MPAs—combined with major ecological, spatial, and operational differences from terrestrial protected areas—restricts direct comparison of staffing adequacy across contexts and highlights the need for more standardized global reference points.

Protected areas are more severely understaffed in the ocean

Caveats notwithstanding, our findings align with assessments of terrestrial protected areas but indicate a more pronounced workforce deficit in marine systems. Terrestrial protected areas are estimated to employ approximately 555,000 personnel across ~20 million km², corresponding to ~37 km² per person (Appleton et al. 2022). This level of staffing is already considered insufficient for effective management. By contrast, MPAs are supported by fewer than 100,000 personnel across ~36 million km², corresponding to ~400 km² per FTE. The contrast between terrestrial rangers and their in-site-focused MPA counterpart is even starker: while the estimated number of rangers on land is ~286,000 FTEs (i.e. 72 km² per person), we estimated only 28,000 in-site-focused FTEs dedicated to the protection of oceans (i.e. ~1300 km² per FTE). While direct comparisons on adequate staffing numbers between terrestrial and marine sites should be treated with caution, taken together, these results indicate an order-of-magnitude lower staffing density in the ocean than on land. Protected areas are thus substantially under-resourced in both marine and the terrestrial environments.

Workforce is constrained but linked to protection quality

Across regions and governance contexts, workforce composition is heavily skewed toward leadership roles, with many technical and functional positions absent or near zero. For example, more than 20% of the sites surveyed lacked any personnel fully dedicated to site duties. Most MPAs therefore lack dedicated capacity for core functions such as monitoring, enforcement, outreach, scientific assessment, and adaptive management—activities consistently linked to MPA effectiveness (Edgar et al. 2014; Gill et al. 2017; Grorud-Colvert et al. 2021). Similar patterns have been reported in regional studies, including Indonesia (Capriati et al. 2026), where most MPAs fell below minimum staffing thresholds. These results indicate that constraints extend beyond total personnel, with highly limited functional capacity within teams reducing operational resilience, limiting delivery and assessment of core management functions, and constraining the ability to evaluate effectiveness, with implications for accountability, investment, and community leadership and support.

Staffing levels showed little consistent relationship with MPA external characteristics such as remoteness, GDP per capita, latitude, or designation year. Notably, as already documented for 36 MPAs in Indonesia (Capriati et al. 2026), staffing did not increase proportionally with MPA size. Instead, higher staffing was most consistently associated with fully or highly protected MPAs and particularly with Blue Parks, suggesting that stronger protection status coincides with greater operational investment, although causality likely operates in both directions. These patterns have important implications for 30×30 implementation. If small MPAs require a minimum level of capacity to cover all roles, then expanding protection through many small sites would require disproportionately greater investment and workforce expansion than creating fewer large MPAs (McCrea-Strub et al. 2011). To expand MPA personnel, shared staffing models may offer a scalable approach. This is illustrated by Australia, where staff are responsible for multiple sites, enabling specialized capacity to be distributed across MPAs without duplicating full teams at each location (Director of National Parks 2025). Within this context, technology further amplifies workforce capacity rather than substituting staff, as effective adoption depends on sufficient personnel to implement and maintain it, creating a reinforcing loop in which better-staffed MPAs benefit more, potentially widening disparities unless workforce investment keeps pace.

The risks of understaffing: ecological and economic implications

These workforce and coordination deficits directly constrain ecological and socio-economic outcomes by limiting the implementation of core management functions (Waldron et al. 2022; Grorud-Colvert et al. 2021; Coad et al. 2019). Surveillance, monitoring, enforcement, outreach, research, and adaptive management are consistently associated with MPA effectiveness (Grorud-Colvert et al. 2021; Edgar et al. 2014; Geldmann et al. 2013), and their absence reduces the ability to detect, prevent, or respond to ecological and social change. As a result, many MPAs risk functioning as “paper parks,” with limited capacity to halt biodiversity loss, support population recovery, or sustain ecosystem services (Gray et al. 2017; Relano et al. 2022; Di Minin and Toivonen 2015; Christie et al. 2017), and consequently limited ability to demonstrate socio-economic returns that justify sustained or increased investment.

These constraints sit within a broader mismatch between conservation ambition, investment, and implementation capacity. Estimates suggest that achieving global MPA targets will require approximately $15.8 billion annually, compared with current spending of roughly $1.2 billion (Waldron et al. 2022; Philips et al. 2025). Biodiversity finance is also unevenly distributed, with marine and coastal systems receiving a small fraction of total flows despite covering most of the planet (UNEP 2022). Our results suggest this gap reflects not only underinvestment, but also limited workforce capacity to translate funding into operational delivery and measurable outcomes. Without sufficient staffing, skills, and enabling systems, conservation finance cannot be fully converted into effective management or demonstrable ecological and socio-economic returns, constraining biodiversity recovery, fisheries rebuilding, coastal protection, and climate regulation.

Closing this gap therefore requires both increased investment and improved translation of resources into operational capacity through integrated workforce development, technology, monitoring, and knowledge systems (see recommendations, Box 1). Staffing alone is necessary but insufficient for effectiveness; without appropriate governance, authority, and community engagement, increases in personnel will not achieve intended outcomes (Geldmann et al. 2019; Coad et al. 2019).

Looking forward

Protecting 30% of the world’s ocean will require major workforce expansion, likely to several million people. Our results show that an untapped potential that could help close this gap may already exist: fishers, divers, boat captains, tourism operators, and others active in and around MPAs. Provided that MPAs possess adequate management and resources to properly support, train, and integrate this workforce, these actors can contribute to several necessary MPA related activities, such as monitoring, education, surveillance, outreach, and stewardship (Ward-Paige 2014; Scyphers et al. 2015).

Conclusions

Meeting global biodiversity targets will depend as much on people and systems as on the designation of protected area extent. Our findings highlight that workforce capacity has not kept pace with expanding conservation commitments, creating a persistent implementation deficit. Given the importance of MPAs, understaffing should not be taken as a specific conservation problem, but as a fundamental component of the broader ocean economy workforce. If society is investing heavily in fisheries, shipping, offshore wind, coastal development, tourism, aquaculture, and marine technology, then it must also invest in the workforce required to sustain the biodiversity and ecosystem services that those sectors ultimately depend on.

Box 1: Recommendations for Strengthening the MPA Workforce

MPAs do not manage themselves—people do. Yet, marine protection targets are expanding faster than the workforce needed to implement them. Here, we provide key recommendations for strengthening workforce systems:

1. Invest in Major Workforce Expansion

- [ ] Substantially increase investment in MPA workforce capacity alongside spatial expansion targets such as 30×30.
- [ ] Prioritize expansion of site-level operational staff (e.g., rangers and guardians) responsible for surveillance, monitoring, implementation, enforcement, and community engagement.
- [ ] Mobilize latent workforce capacity through structured integration of fishers, divers, tourism operators, Indigenous stewards, community groups, students, and other ocean users.

2. Professionalize the MPA Workforce

- [ ] Ensure MPA roles are stable, safe, well-compensated, and professionally viable to compete with other rapidly growing blue economy sectors.
- [ ] Expand learning opportunities, leadership, development mentorship and technical training; strengthen workforce retention through clearer standards and competencies; institutionalize certification systems and support long-term career pathways across functional roles.
- [ ] Deploy technology strategically to improve effectiveness while investing in the skilled personnel required to implement and maintain these assets.

3. Monitoring and Evaluation

- [ ] Develop MPA performance systems that integrate governance, workforce, implementation, outcomes, threats, compliance, and socio-economic monitoring in near real time.
- [ ] Improve harmonization and interoperability across MPA databases and reporting frameworks to enable continuous, scalable, and transparent evaluation of effectiveness.
- [ ] Develop evidence-based staffing guidance and operational models tailored to different MPA contexts and models.
- [ ] Integrate workforce and performance data into the adaptive management cycle to identify capacity gaps, assess return on investment, adjust plans, and guide future funding and governance decisions.

Methods

Questionnaire development and survey deployment

We developed a focused, MPA site-level questionnaire to capture core dimensions of the global MPA workforce (Table A1). The questionnaire was programmed using the formr survey framework version 0.23.0 (Arslan et al. 2020). It was deployed on a custom, GDPR-compliant server hosted by Hetzner in Germany and made accessible via the Marine Conservation Institute. Direct integration with Protected Planet, which shares the World Database on Protected Areas (WDPA), allowed respondents to select, view, and verify the MPA site(s) to which their responses applied. Although 17,026 MPAs could be selected, respondents could alternatively describe their MPA(s) using free text.

For each MPA, or pooled set of MPAs, respondents characterized formal staffing and functional roles (including partial or full-time equivalents, FTEs), as well as context on technology deployed and the presence of other actors operating within or near the MPA. Additional questions captured respondent information, and perceptions of workforce adequacy.

To protect sensitive information, no site-identifiable workforce data are reported. Analyses included only responses that progressed beyond the first question (i.e. "Select your country") and successfully identified at least one MPA or provided comments allowing us to do so.

Before deploying the questionnaire, test runs were performed with a few MPAs and we refined the questionnaire based on feedback. Tutorial videos on the purpose and structure of the study were shared in the questionnaire to guide respondents.

To capture data on a global scale, we implemented a three-phased survey distribution strategy. Phase 1 used broad outreach through professional networks, listservs, newsletters, and social media. Phase 2 consisted of exhaustive, targeted, and personalized outreach to all management organizations listed for marine protected areas in WDPA, complemented by systematic web and academic searches to identify contacts where management authorities were not readily available; in total, 347 initial and 324 follow-up emails were sent. Phase 3 enabled snowball sampling through participant referrals. Engagement was further supported through a global webinar (521 live attendees) delivered to MPA-specific stakeholders in partnership with Open Communications for the Ocean (OCTO, www.octogroup.org).

Variables and data sources

MPA-level variables

For each MPA or sub-MPA entity (parcel/zone), we extracted and used the following 19 variables:

- MPA ID: the unique identifier of the MPA set by the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), from WDPA under the name SITE ID (formerly WDPA ID).
- MPA PID: the parcel ID, whenever the MPA is composed of different parcels, from WDPA under the name SITE PID (formerly WDPA PID).
- geographic country: the country or territory where the MPA is located, from WDPA.
- administering country: the sovereign country associated with the MPA, from WDPA.
- geographic continent: the continent where the MPA is located (Africa, Asia, Europe, Latin America and the Caribbean, Northern America, or Oceania).
- administering continent: the continent associated with the sovereign country of the MPA (Africa, Asia, Europe, Latin America and the Caribbean, Northern America, or Oceania).
- realm: marine (> 90% of area in marine realm), coastal (10–90% on land), or terrestrial (> 90% of area on land), from WDPA.
- surface area: the size of the MPA or sub-MPA entity (parcel/zone) in km^2, derived from the geometry (see below).
- GDP: the per-capita gross domestic product of the parent country adjusted for purchasing power parity, from World Bank (indicator NY.GDP.PCAP.PP.CD).
- designation: the designation of the site, from WDPA.
- designation type: the category or type of protected area as officially designated or proposed (National, Regional, International, or Not Applicable), from WDPA.
- government type: the entity responsible and accountable for making decisions about how the MPA is managed, from WDPA.
- IUCN category: the IUCN category (Ia, Ib, II, …), from WDPA.
- stage of establishment: the stage of establishment of the MPA provided by MPAtlas but simplified by us into four categories: proposed, designated, actively managed or implemented, and unknown.
- designation year: the year of formal designation, from WDPA.
- level of protection: the level of protection from The MPA Guide provided by MPAtlas, simplified to two levels (fully/highly vs other); we classified an MPA as fully/highly if any of its assigned protection levels were in that category.
- no take zone classification: indicates if the taking of living or dead natural resources is strictly prohibited in all or part of the MPA, from WDPA—possible values are all, part, or none.
- blue park status: the Blue Park certification of the site, added manually after consulting MPAtlas.org.
- blue spark status: whether the MPA is a Blue Park candidate, added manually.

- green list status: the Green List status of the site, from iucngreenlist.org.
- geometry: the digitized geographic information providing the outline(s) and location(s) of the MPA (polygons, set of polygons, and/or points), from WDPA.

Information for all sites was obtained from the WDPA, except four sites absent from the WDPA, which were sourced from MPAtlas.

Site-level variables

We defined a *site* as the single MPA or set of nearby MPAs that are managed by the same workforce (see *Spatial data processing* below). While spatial attributes of sites can be readily obtained by computing relevant statistics after merging geometries, variables carried over from the MPA level required a set of rules for aggregating MPAs. We prepared the following 22 variables accordingly:

- site ID: the set of MPA IDs defining the site.
- surface area: the size of the site (in km^2), encompassing all possible polygons after dissolving any overlaps (see *Spatial data processing*).
- latitude: the latitude of the centroid of all polygons forming a site, computed by us (see *Spatial data processing*).
- remoteness: the human population within a 100-km circle (i.e. regional area) with its center defined by the centroid of the polygon or multi-polygon associated with each site—using data from NASA (Gridded Population of the World, Version 4 (GPWv4): Population Count, Revision 11).
- geographic country: see MPA-level variables.
- administering country: see MPA-level variables.
- geographic continent: see MPA-level variables.
- administering continent: see MPA-level variables.
- realm: retain coastal if marine-coastal combination amongst the combined MPAs.
- GDP: see MPA-level variables.
- designation: see MPA-level variables.
- designation type: retain the highest category (International > National > Regional) amongst the combined MPAs.
- government type: see MPA-level variables.
- IUCN category: retain the highest category (VI > V > …> I) amongst the combined MPAs.
- stage of establishment: see MPA-level variables.
- designation year: use the most recent year.
- level of protection: see MPA-level variables.
- no take zone classification: if mixed amongst the combined MPAs, becomes "part".
- blue park status: see MPA-level variables.

- blue spark status: see MPA-level variables.
- green list status: see MPA-level variables.
- geometry: the set of MPA geometries.

If information was missing for some MPAs within a site, only available data from other MPAs in the same site during aggregation were used. The aggregation rules defined above would not cover all hypothetical cases, but they resolved the discrepancies encountered in our data.

Respondent-level variables

For the purpose of our study, we defined a *respondent* as the person (or persons) that completed the online survey, with possible interruptions, but without switching internet browsers or clearing the browser cache. For each respondent, we used eight variables retrieved from our survey:

- ID: a unique identifier for each respondent.
- MPA ID: the name and site ID of the MPA, or sets of MPAs, for which the respondent filled the survey (see *MPA-level variables*). Either selected amidst a list of all non-terrestrial protected areas listed for the selected country in WDPA (as of 2024-12-23), or inferred from the name or comment left by the respondents (two cases), or clarified after contacting respondents (four cases). In addition, four MPAs referred to by respondents were not present in WDPA, but were present in MPAtlas. After manual inspection in WDPA and MPAtlas, we then adjusted ten MPA IDs for which we identified equivalent MPAs with more accurate information (five UNESCO Man and the Biosphere Reserves or World Heritage sites, one Ramsar (www.ramsar.org) site, four MPA IDs referring to a small portion of a larger MPA). Finally, we removed four MPAs within pools as other MPAs already included in such pools had matching geometries and more information associated.
- FTE numbers: the number of full-time equivalent personnel working on the selected MPA(s) and contributing to achieving their goals, broken down into six formal roles (leadership focused, in-site focused, support focused, stakeholder focused, science focused, and others) and provided in 0.05 FTE increments.
- accuracy in FTEs: whether the confidence in the FTE numbers provided was high, medium, or low.
- technology: technology or other aids used to help the MPA workforce expand its effectiveness, selected from satellite technologies, radar technologies, underwater acoustic technologies, drone technologies, MPA evaluation technologies, and reporting tools.
- operators: entities operating seasonally or more within or nearby the MPA who are not formally responsible for the MPA.

- respondent in leadership position: whether or not the respondent held a leadership position within the MPA.
- adequacy: the perception of adequacy of the current workforce for ensuring the specific MPA can successfully achieve the objectives for which it was established, as one of five possible categories: fully adequate, mostly adequate, moderately adequate, somewhat adequate, not adequate.

In addition to these variables, we carried over all 22 site-level variables to the respondent level. Since some respondents provided data for multiple sites rather than for single sites alone, we applied the aggregation rules described above (see site-level variables) and introduce the following new rules:

- country: MPAs pooled across Australia, Cocos (Keeling) Islands, Christmas Island and Norfolk Island, considered as Australia.
- government type: retained the highest category amongst the combined MPAs (joint governance > federal or national ministry or agency > sub-national ministry or agency).
- stage of establishment: "actively managed or implemented" and "designated" were combined into "actively managed or implemented".

Spatial data processing

Polygon-derived areas were used for all spatial analyses. For sampled MPAs represented in WDPA only as points (i.e. without polygons), each had a similarly named and spatially overlapping polygon-based site found in WDPA; in these cases, the geometry was substituted. For non-sampled MPAs represented in WDPA only as points and with non-zero reported surface area, we used the R package wdpar (Hanson 2022) to generate circles centered on those points with an area equal to the reported value. At each aggregation step required during the preparation of datasets (i.e. parcels/zones -> MPAs -> sites -> multisites), we merged and dissolved all intersecting polygons to avoid double counting of areas where polygons overlapped. To estimate the total surface area covered by sampled and all MPAs, we only retained MPAs classified as fully marine or coastal in WDPA and discarded terrestrial protected areas. To assess the remoteness of each site, we assessed the number of inhabitants within a 100-km radius with its center defined by the centroid of the polygon, or multi-polygon, associated with each site. The same centroid was used to extract the latitude associated with each site.

Computational definition of sites

There are many overlapping MPAs due to the multiple legal designations that can co-occur in the same area. For example, different IUCN management categories within the same site have different MPA IDs and geometries. The same applies to alternative designation types (e.g. national vs regional). Therefore, each MPA within a site does not necessarily possess its own independent workforce, but the personnel represents a collection of MPAs as a whole. The authoritative databases did not include attributes that allow for identification of sites composed of different MPAs. We therefore defined sites based on the extent of spatial overlap between MPAs. Specifically, we used three alternative computational definitions: (i) a site corresponds to a single MPA or a set of MPAs with geometries intersecting with one another (i.e. overlap or joint border), (ii) a site corresponds to a single MPA or a set of MPAs with geometries presenting at least 50% spatial overlap, and (iii) a site corresponds a single MPA (i.e. one MPA ID). The first computational definition best corresponded to actual sites within the sampled MPAs (based on manual inspection), but it grouped too many MPAs in areas with high spatial density, effectively merging all MPAs from the WDPA in that region. Unless otherwise mentioned, we thus used the second definition of sites when all sites (i.e. sampled or not) are considered.

Prepared datasets

Our analyses are based on four key datasets. Two encompass all variables described in the section *Variables and data sources* and focus on the *sampled* MPAs: one in which each row corresponds to a unique MPA or sub-MPA entity (parcel/zone) (N_{row} = 367) connected to a respondent, and one in which each row corresponds to a different respondent (N_{row} = 190). A third dataset contains the total number of FTEs, the surface area, and the adequacy value associated with each respondent. In this dataset, we encrypted FTE values and surface areas still preserving values as numbers so that analyses can be run on the shared dataset without compromising data privacy. The fourth dataset corresponds to all sampled MPAs (or sub-MPA entity), in addition to all other MPAs listed in the WDPA as of 2026-01-19 with the exception of the UNESCO sites. For this last dataset (N_{row} = 16,867), we only retained as variables the IDs of MPAs or sub-MPA entities (parcel/zone), the realm, the surface area, the geographic country, the administering country, and the geometries.

Workforce predictor analyses

Associations between staffing levels and site characteristics were examined across multiple dimensions to evaluate how workforce adequacy relates to site characteristics, governance, and broader social and ecological contexts. Variables included those known to influence management effectiveness and biodiversity (Edgar et al. 2014; Gill et al. 2017, 2024; Capriati et al. 2026; Ward-Paige et al. 2010; Ban et al. 2019; Hockings et al. 2006). Specifically, we investigated connections between FTEs and: area, latitude, remoteness, continent, realm, GDP, designation, designation type, IUCN category, stage of establishment, designation year, level of protection, no take zone classification, formal conservation recognition (Blue Parks and IUCN Green List status), functional roles, and available technologies (see section *Variables and data sources* for details). Analyses involving GDP were restricted to MPAs within sovereign states, excluding overseas territories due to attribution complexity and limited sample size.

In graphical descriptions, FTE numbers associated with multiple sites were excluded, while those associated with multiple MPAs within a single site were retained (using the site definition where an intersection is sufficient; see *Spatial data processing*). When multiple respondents reported FTE numbers for the same site, values were averaged to prevent double counting.

To formally investigate relationships between staffing levels and key site characteristics, we fitted a series of linear mixed-effects models (LMMs). Analyses used the respondent-level dataset after excluding responses covering multiple sites. Respondents reporting for multiple MPAs were retained when those MPAs corresponded to a single site. The response variable was the natural logarithm of the FTE numbers after adding 0.1 (i.e. log(FTE + 0.1)) to avoid undefined values. To study the full relationship between a given predictor and staffing (Morrissey and Ruxton 2018) single fixed-effect predictor. Surface areas and GPD were log-transformed to improve model fit, while remoteness was parameterized as log(population size + 1). Latitude was analyzed as its absolute value to reflect distance to the equator. To account for duplicates in the data (different respondents answering for the same sites), all models included site IDs as random effects. Fixed effects were tested using likelihood ratio tests of maximum likelihood fits, with the null distribution of the test statistics generated by parametric bootstrap (1,000 iterations). Predictions were computed as partial differential effects, with confidence intervals computed so as to account for the uncertainty in fixed effects only, thus corresponding to the likelihood ratio tests.

Global workforce estimations

We estimated global MPA workforce capacity using a resampling-based extrapolation of FTE numbers from single-site responses, excluding all FTE numbers for which respondents indicated low accuracy. The resulting figures indicate the workforce needed to maintain existing MPAs and support expansion, without prescribing exact staffing formulas.

We performed three main estimation tasks: (i) estimating the current global workforce (i.e. at sampling time: April–October 2025), (ii) estimating the projected global workforce with 30% of the ocean protected assuming a similar distribution of FTEs as found in the current workforce, and (iii) estimating the projected global workforce with 30% of the ocean protected assuming a number of FTE per site sufficient to achieve the MPAs objectives. The general approach was the same of all three tasks: (i) characterise the distribution of non-zero FTE numbers, (ii) determine the number of sites to be populated, (iii) randomly sample an FTE number for each site from the distribution, (iv) assign zero FTEs to a proportion of sites, and (v) sum the FTE across all sites to obtain a global estimate. This procedure was applied to both total staffing and site-level operational staff.

Estimation of the current global workforce

As a source of FTE numbers, we used either the total number of FTE or the number of in-site-focused FTEs observed across all retained sites (i.e. responses for single sites with medium or high FTE accuracy), except the Great Barrier Reef (MPA ID 2628), which is uniquely large and well staffed. To determine the number of sites to be populated, we considered all marine and coastal MPAs with "established" status and polygon-based spatial records in the WDPA (non-zero area).

To assess the robustness of key assumptions behind our estimation approach, we compared estimations obtained under the three alternative computational definitions for sites mentioned above (see section *Computational definitions of site*). We also compared five alternative distributions of FTE to estimate the current workforce: (i) the empirical distribution (i.e. no model fitting), (ii) the log-normal distribution fitted to the observed FTE numbers, (iii) the gamma distribution fitted to the observed FTE numbers, (iv) the empirical distribution for FTEs below a threshold and the log-normal distribution fitted to the FTE numbers above that threshold, and (v) the empirical distribution for FTEs below the threshold and the gamma distribution fitted to FTE numbers above that threshold. The threshold was defined as the maximal number of FTEs above which at least 50 sites had been sampled. Finally, we varied the proportion of unstaffed sites between 0 and 20%. For each estimation scheme (definition of site, statistical approach, and proportion of unstaffed sites), the estimation procedure was repeated 1,000 times to generate confidence intervals around the global workforce estimate based on the empirical quantiles obtained.

Projection of global workforce to protect 30% of oceans under current FTEs

For projecting FTE needs to protect 30% of the ocean, we followed the approach described above, with the only difference being the number of sites to be populated, which was set to correspond to 30% ocean protection. We relied on the recent study by Rechberger et al. (2025), which projected that ~190,000 sites are needed—for our analysis we used 186,293, the exact value provided in the Supplementary Table 3 of that study.

Projection of global workforce to protect 30% of oceans under adequate staffing

For projecting future numbers under adequate staffing, we proceeded as described above, using different sets of FTE numbers. We initially considered three possible sets of FTEs reflecting adequate staffing for both total and in-site-focused personnel: (i) the FTE numbers observed across all retained sites with a level of protection corresponding to the fully or highly category, (ii) the FTE numbers observed across all retained sites awarded as Blue Parks, and (iii) the FTE numbers observed across all sites where respondent judged their staffing as at least moderately adequate. We only retained FTEs from sampled Blue Parks since other sets of FTE numbers did not significantly differ from the larger unrestricted pool of FTE numbers across sampled independent sites (Mann Whitney U test, fully/highly: W = 3,121, p = 0.063; mostly/moderately adequate: W = 11,370, p = 0.86; FTEs associated with low with confident FTEs estimation being excluded from all comparisons).

Staffing adequacy analysis

We used generalized linear models (GLMs) to study how adequacy was predicted from the staffing level. The data used to fit this model were the same as described in the section *Workforce predictor analysis*, but this time the family of the model was binomial (logit link) rather than gaussian. The response variable was binary, with adequacy classified as one when moderate or higher and zero when lower than moderate. Other pooling schemes were considered but resulted in lower goodness of fit. The single fixed-effect predictor considered was log(FTE + 0.1). This time we discarded random effects since site IDs exerted little influence on the results and would make it impossible to keep the adequacy ratings confidential while sharing the data. Likelihood ratio tests and predictions were computed as described for LMMs.

Software

All analyses were performed in R version 4.6.0 (R Core Team 2026). Information retrieved from WDPA was processed with the R package wdpar version 1.3.9 (Hanson 2022). MPAtlas (mpatlas.org) spatial data were processed using the R package sf version 1.1-1 (version 1.1-0; Pebesma 2018). To handle spatial computation bottlenecks, we used the R packages terra version 1.9-34 (Hijmans et al. 2026) and exactextractr version 0.10.1 (Baston 2025). World Bank data were retrieved using the R package WDI version 2.7.10 (Arel-Bundock 2026). Statistical models were fitted using the R package spaMM version 4.6.65 (Rousset and Ferdy 2014). The code used in this project, consisting of a collection of R scripts and an accompanying R package, is available as MPAworkforce (https://doi.org/10.5281/zenodo.21076349).

Author contributions

Conceived project: MA, LN, AC, LK, KSW, EPP, CWP
Designed the experiment and collected data: CWP, AC, EPP, MA
Inspected and validated the data: EPP, CWP, AC
Analyzed the data: AC
Writing: CWP, AC, EPP, MA
Editing: LN, LK, KSW
Illustration: AC, CWP

Ethics statements, Conflicts of interest

Funders, Blue Nature Alliance, were involved in the following ways: LN, KSW, LK are co-authors. They helped design the study and review drafts, but did not perform the experiment, handle, or analyze the data.

Data availability

De-identified data used in this study are available in the Supplementary Information and associated source data files. All data were stored on secure GDPR-compliant servers hosted in Germany during the study.

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Figures

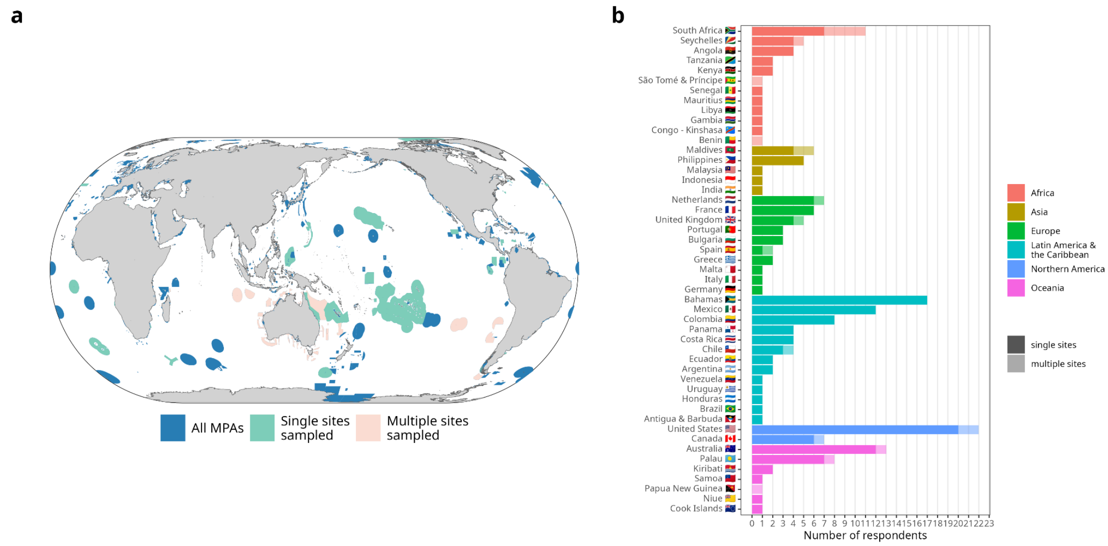

Figure 1. Global MPA representativeness

Surveyed MPAs encompass a wide range of spatial, ecological, and social contexts. **a**, Geographic coverage of responding sites relative to all global MPAs. **b**, Coverage of respondents by administering continent and country (N_{resp} = 190).

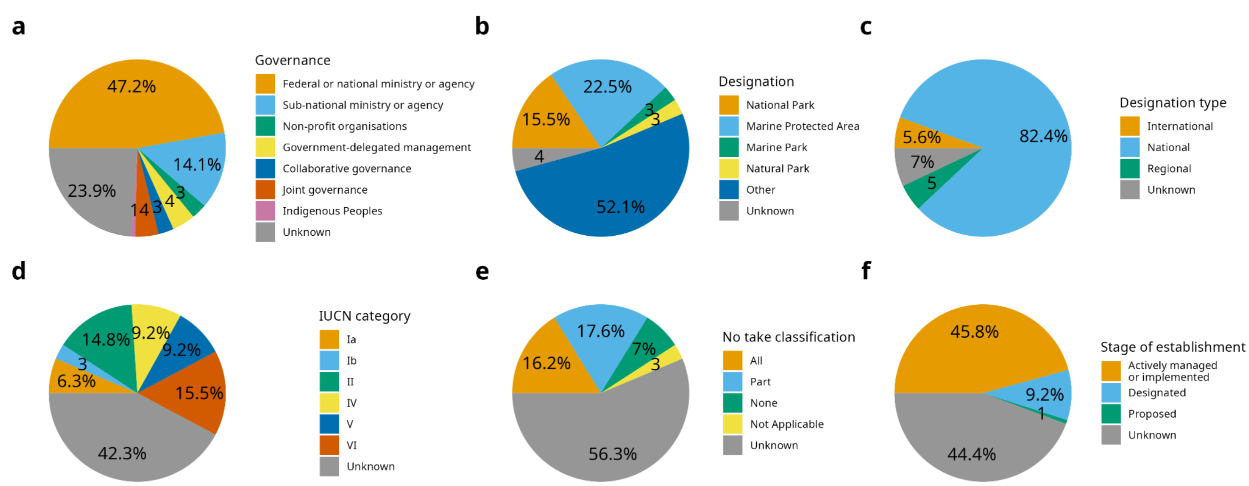

Figure 2. Characteristics of MPA sites sampled

a, Governance type. **b**, Designation. **c**, Designation type. **d**, IUCN category. **e**, No take zone classification. **f**, Stage of establishment from MPAtlas. For the purpose of visual clarity, percentages below 5% are rounded to the closest integer and displayed without the "%" sign. Only responses associated with MPAs corresponding to single, independent, sites were considered (N_{sites} = 142).

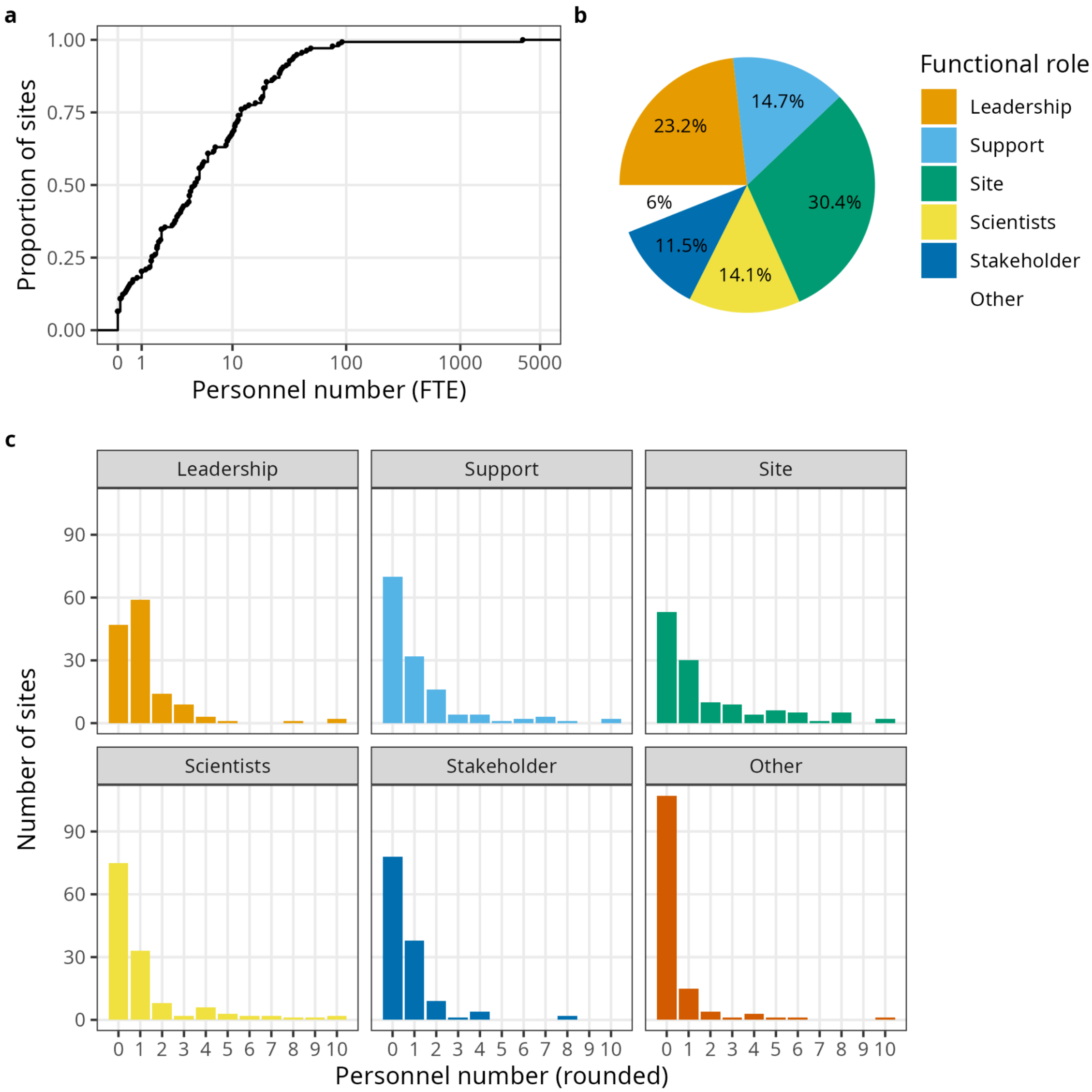

Figure 3. Workforce characteristics in MPA sites sampled

a, Empirical cumulative distribution function indicating the cumulative fraction of sites for which the number of personnel was lower or equal to a particular value (e.g. 50% of MPAs had less than 4.5 full time equivalents (FTEs), and 67.5% had less than 10). **b**, Average proportion of FTE across functional roles. **c**, Distributions of MPA sites by functional roles, with the right-tailed end of the distribution truncated at 10 FTEs. Duplicates per independent sites were averaged and only values from respondents classifying their FTE-assessment quality as medium or high were included (N_{sites} = 138).

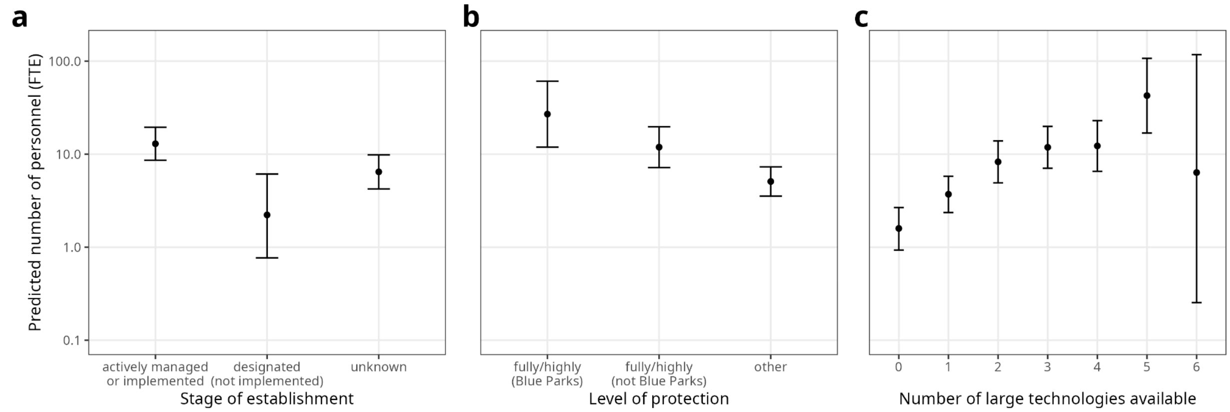

Figure 4. Personnel number and internal MPA characteristics
Predicted full time equivalents (FTE) across: **a**, stage of establishment, **b**, level of protection, and **c**, the number of large technologies available (N_{resp} = 166, N_{sites} = 138). Since only a single site has the stage of establishment "proposed", it is omitted from the display. Predictions are partial dependent effects stemming from linear mixed-effect models including the *x* variable as the only fixed effect predictor and the site as a random effect, with error bars showing 95% confidence intervals based on fixed-effect variances.

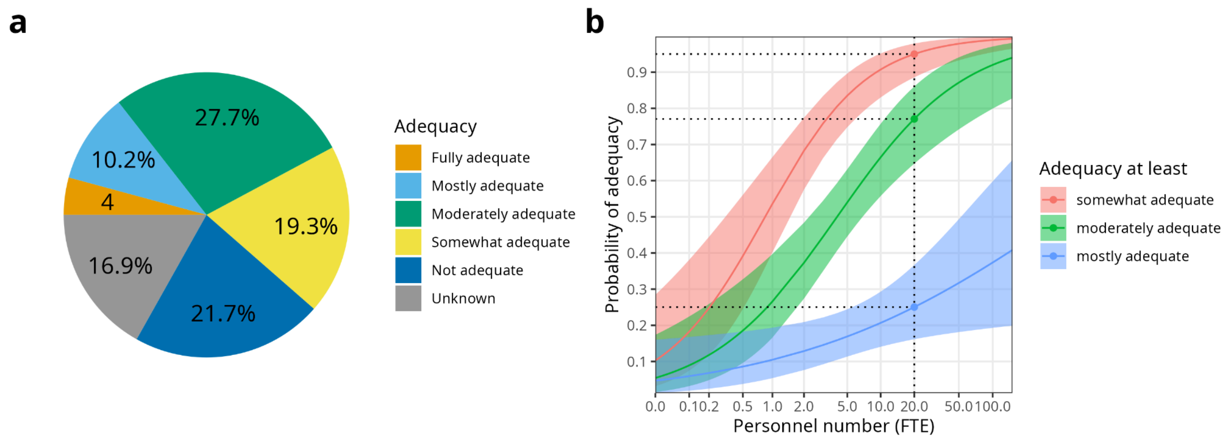

Figure 5. Self-reported adequacy
a, distribution of self-reported staffing adequacy (N_{resp} = 190). **b**, predicted relationship between the probability for the reported adequacy to exceed a certain level according to the reported number of personnel within the same sites (N_{resp} = 138, N_{sites} = 116). In **b**, predictions are partial dependent effects stemming from a logistic mixed-effect model including log(FTE + 0.1) as the only fixed effect predictor and the site as a random effect, with error bars showing 95% confidence intervals based on fixed-effect variances. Dotted lines illustrate predicted probabilities for 20 FTEs, which corresponds both to the mean number of FTE in sampled Blue Parks and the recommended number of FTEs according to Capriati et al. (2026).

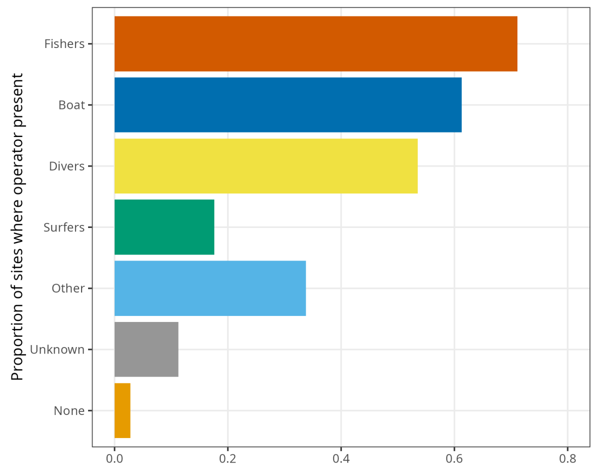

Figure 6. Potential workforce contributions from local actors
Proportion of non-staff actors operating within or near MPAs present in each of the 142 independent sites surveyed.

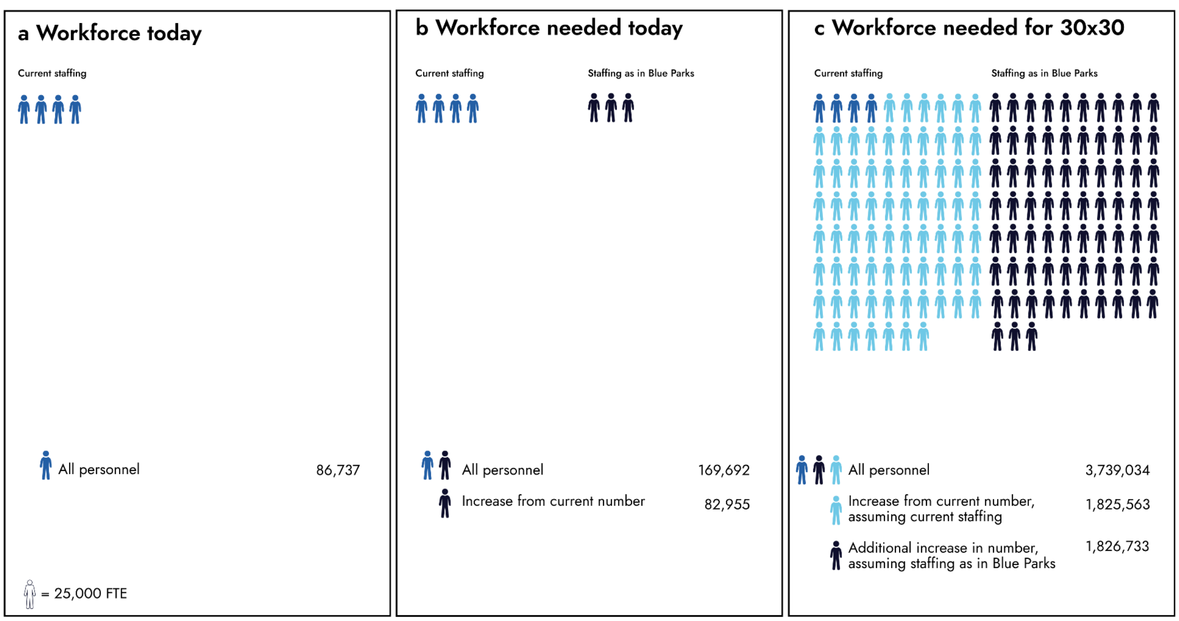

Figure 7. Global MPA workforce and extrapolated capacity
a, Estimated current global MPA workforce. **b**, Estimated required numbers to manage existing MPAs effectively. **c**, Indicative FTEs needed for adequate staffing to cover 30% of the ocean. Each silhouette represents approximately 25,000 FTE personnel; medium-blue represents existing personnel; light-blue represents further personnel required for managing 30% of the ocean under current staffing density; dark-blue represents additional personnel numbers required for efficiently managing current or future MPAs.

Tables

Table 1. Predicted personnel needs

The first row provides the estimate of the current number of personnel in full time equivalents (FTEs). Other rows provide projected needs based on the number of MPAs estimated as of 2025, or based on the number of MPAs estimated to be needed in 2030 (Rechberger et al. 2025). Two tallies of personnel are considered: all staff, or in-site-focused staff (≈ rangers in Appleton et al. 2022). Projected needs are estimated based on two staffing distributions in our sample shown in columns: the one currently observed across all MPAs (Personnel as is), and the one currently observed within blue parks (Personnel as blue parks).

		Total Personnel		Site-focused Personnel	
		as is	**as Blue Parks**	**as is**	**as Blue Parks**
2025	**Personnel (FTE)**	86,737		28,066	
	Needed (FTE)	0	169,692	0	54,184
	Increase needed (FTE)	0	82,955	0	26,118
	Needed / current	1.0	2.0	1.0	1.9
	Current / needed (%)	0.0	51.1	0.0	51.8
2030	**Needed (FTE)**	1,912,300	3,739,034	617,852	1,193,869
	Increase needed (FTE)	1,825,563	3,652,296	589,785	1,165,803
	Needed / current	22.0	43.1	22.0	42.5
	Current / needed (%)	4.5	2.3	4.5	2.4

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Table A1. Questionnaire

Question
Part A. Identify your MPA(s). 1. Select your country 2. Select your MPA(s) *Lists sourced from Protected Planet, and respondents could open the site webpage to confirm. *If a site could not be found, they could add information. *Multiple sites could be responded on at the same time — “Pooled” sites. **Part B. Tell us about this MPA(s)** 1: Who works on this specific MPA? Including yourself, how many formal staff work on this MPA, and in what roles? Leadership focused; In-site focused; Support; Stakeholder Science; Other; None; I don't know *Partials were allowed, and a calculation was made on the numbers to give the total, which the respondent had to confirm. *Zeros were allowed. **Role definitions: ● Leadership focused – e.g., manager, superintendent, decision maker ● In-site focused – e.g., ranger and ranger-like roles working in the MPA, with and without enforcement capabilities ● Support focused – e.g., supporting staff, administrative support, finance ● Stakeholder focused – e.g., education and outreach ● Science focused – e.g., collecting and analyzing data to address questions ● Other – for roles not listed above ● None – no one works on this MPA in a formal role ● I don't know 2: Technology used to help? ● Satellite technologies, ● Radar technologies ● Underwater acoustic technologies ● Drone technologies ● MPA evaluation technology (e.g., https://www.eoceans.org/mpas) ● Reporting tools: Phone, email, or app reporting for marine species, activities, incidents ● None of the above ● I don't know *Prompts were provided to select from, and they could add their own.

3. Who else is nearby?
Who else operates seasonally or more within or nearby this specific MPA who is not formally responsible for working for this MPA?

- Fishers 🎣
- Divers 🤿
- Surfers 🏄
- Boat operators ⛵
- Other – for operators not listed above
- None – no one uses this MPA 🏝️
- I don't know

*Prompts were provided to select from, and they could add their own.

4. Anything else?
Is there anything else you would like us to know about this specific MPA workforce? Tell us more, so we fully understand.

Part C. Tell us about you.
1. Your role.
2. Your name.
3. Your email.
4. How can we acknowledge you?

Follow up questions:
1. Referrals?
Who else should we hear from for this or other MPAs?
2. Is your workforce adequate?
In your opinion, is this current level of workforce adequate for ensuring this specific MPA can successfully achieve the objectives (fulfil the purpose) for which it was established.

- Fully Adequate – Meets or exceeds all requirements and expectations.
- Mostly Adequate – Meets nearly all requirements with minor gaps.
- Moderately Adequate – Meets most requirements but has room for improvement.
- Somewhat Adequate – Meets a few requirements but falls short in key areas.
- Not Adequate – Does not meet basic requirements or expectations.

3. Can you fill in this survey for another MPA?

Supplementary figures

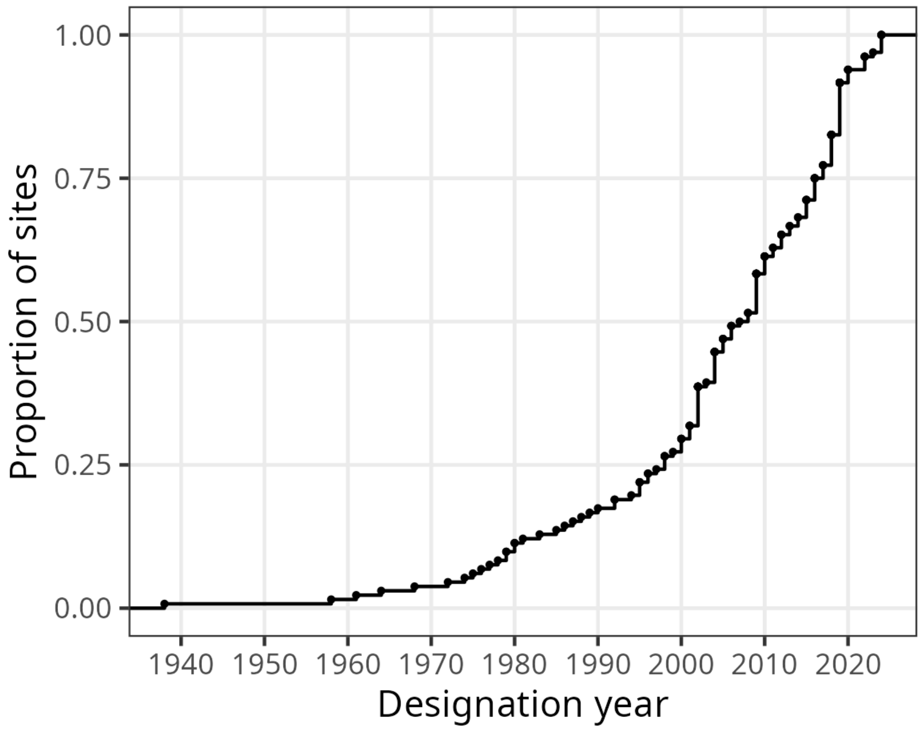

Figure S1. Distribution of designation year

Empirical cumulative distribution function indicating the cumulative fraction of sites (N_{sites} = 132) for which year of designation was lower or equal to a particular value (e.g. 50% of MPAs were updated before 2007).

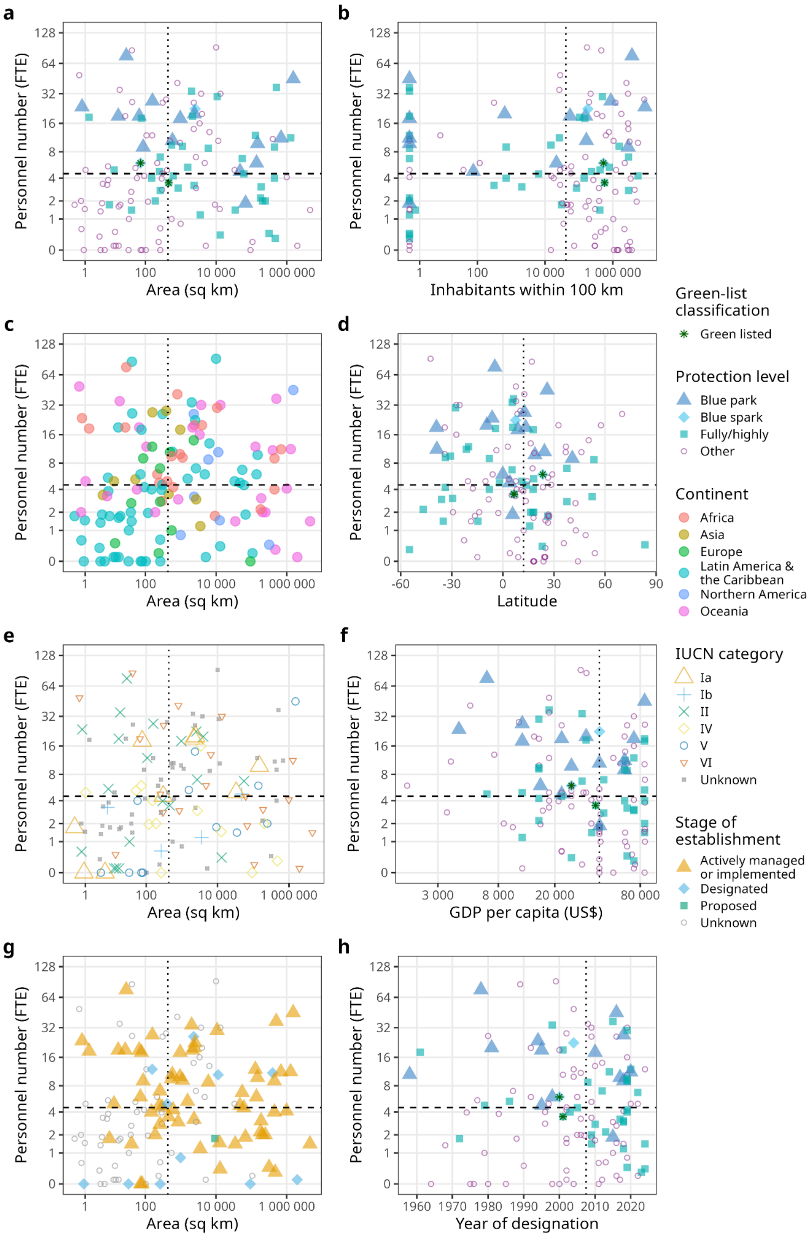

Figure S2. Relationship between MPA sites characteristics and personnel numbers

Panels show area (**a**, **c**, **e**, **g**), human population within 100 km (**b**), latitude (**d**), GDP per capita (**f**), and year of designation (**h**) as predictors, coloured by protection level (**a**, **b**, **d**, **f**, **h**), geographic continent (**c**), IUCN category (**e**), and stage of establishment (**g**). The green asterisk denotes green-listed sites. Dashed horizontal and dotted vertical lines indicate the median personnel number and median predictor value, respectively. Duplicates per independent sites were averaged (N_{sites} = 127–137, depending on the plot) and only values from respondents classifying their FTE assessment quality as medium or high were included. For the purpose of visualisation, we also omitted one site with more than 1,000 FTE (Great Barrier Reef).

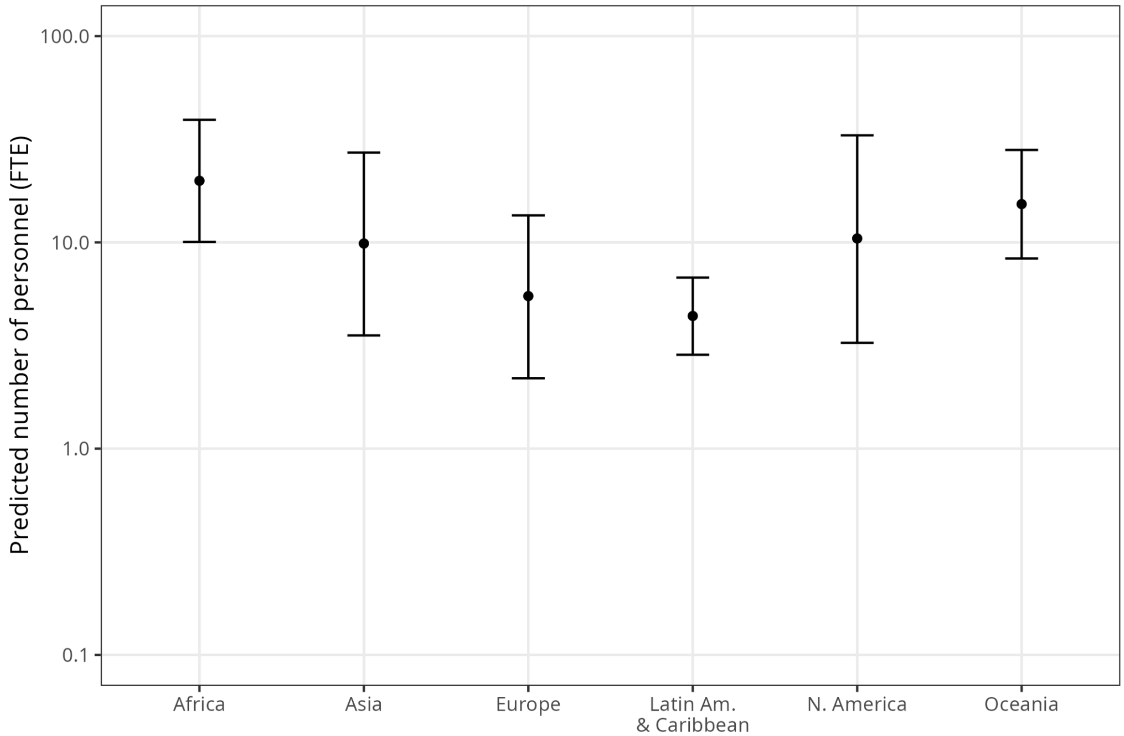

Figure S3. Personnel number per continent
Predicted full time equivalents (FTE) across continents where the MPA sites are located (N_{resp} = 166, N_{sites} = 138). Predictions are partial dependent effects stemming from a linear mixed-effect model including the continent as the only fixed effect predictor and the site as a random effect, with error bars showing 95% confidence intervals based on fixed-effect variances.

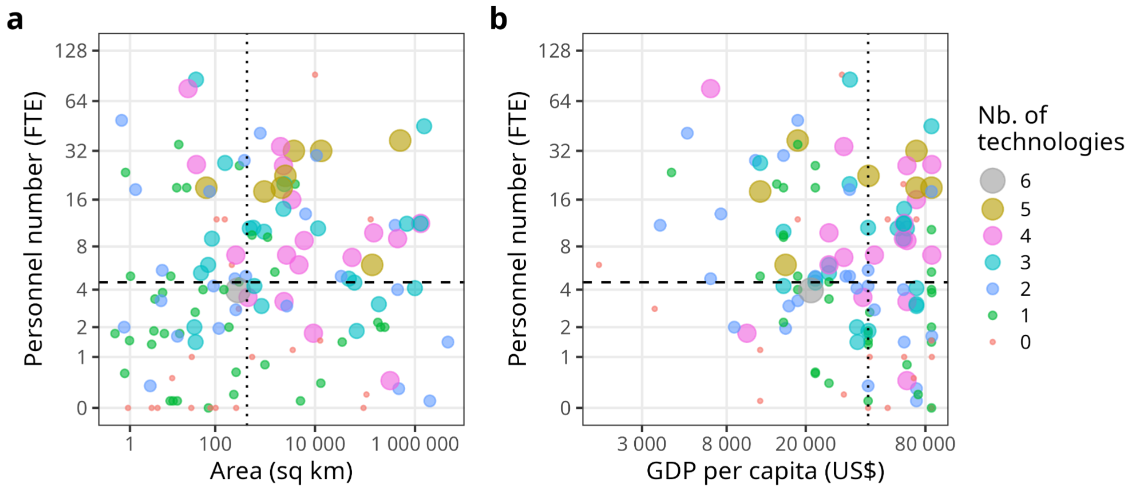

Figure S4. Relationship between large technologies, MPA size, GDP, and personnel numbers

See Fig. S2 for legend details.

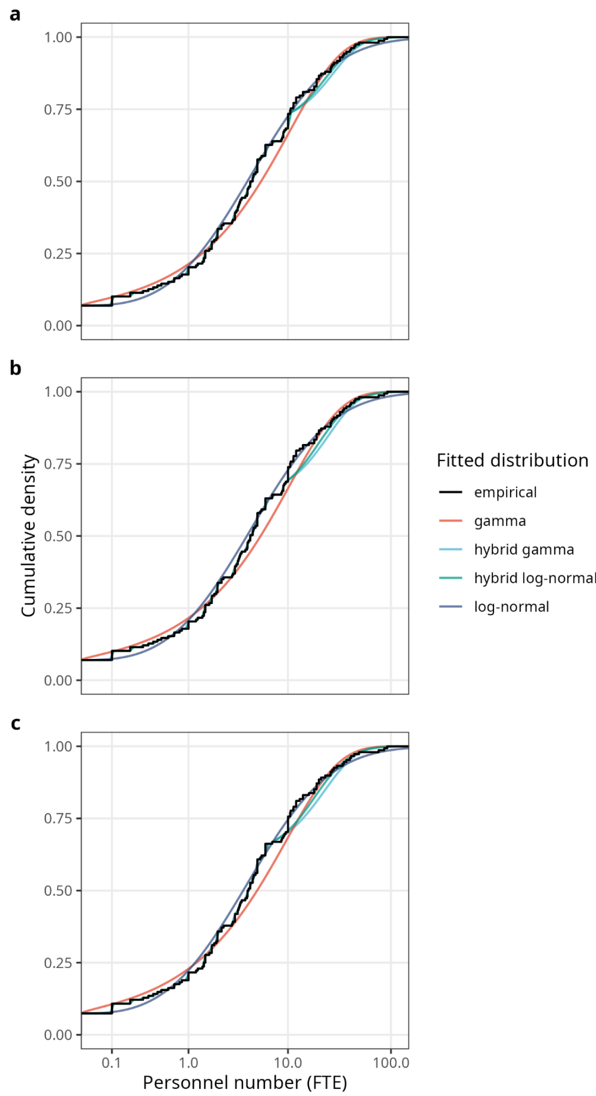

Figure S5. Alternative approximation of the empirical cumulative distribution function for FTE Each plot corresponds to a different number of total sites considered to be independent following alternative definitions of what constitutes a single site: **a**) a single MPA or a set of intersecting MPAs; **b**) a single MPA or a set of MPAs overlapping by at least 50%; **c**) a single MPA. Within each plot the empirical cumulative distribution of the number of FTE is plotted (black line), as well as two parametric fits of such distribution—the gamma and log-normal distributions. We also considered two hybrid empirical-parametric approaches where the empirical distribution is used for the left tail of the distribution, while a parametric fit is applied to the FTE numbers from the 50 sites with the highest staffing within our sample (again, either using the gamma or the log-normal distribution). Hybrid approaches were used so as to faithfully depict low staffing numbers while being able to predict FTE numbers potentially higher than the maximum reported (with the omission of the Great Barrier Reef, see main text).

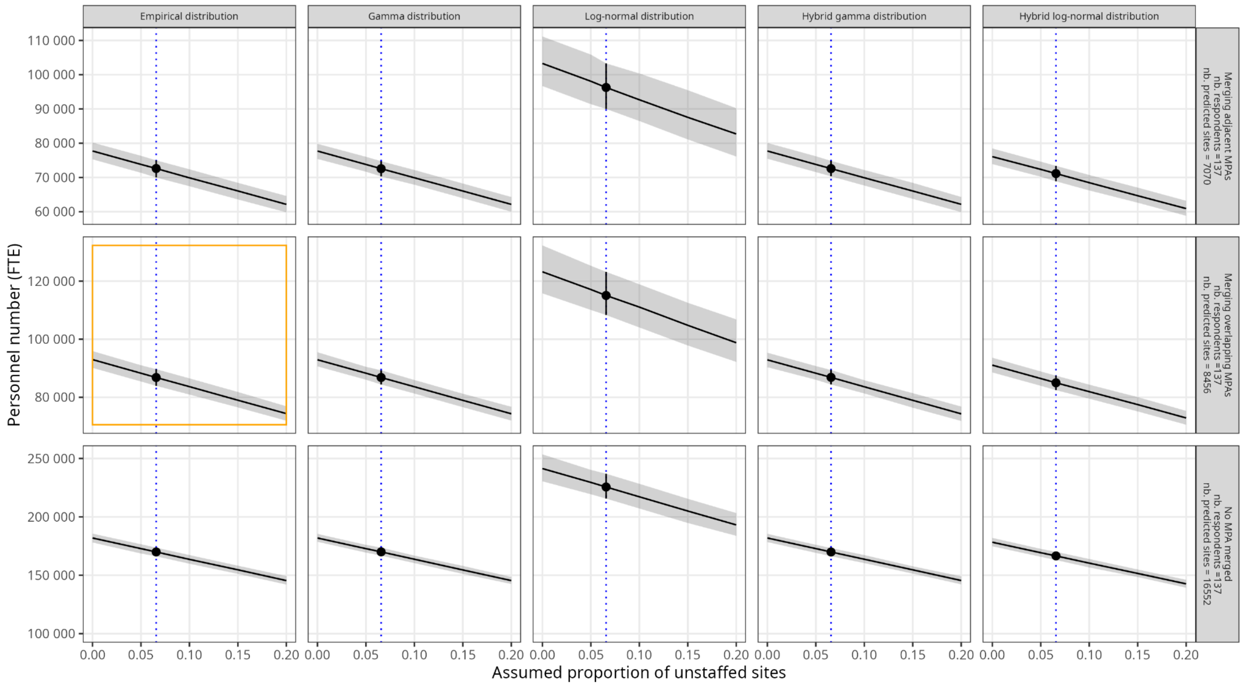

Figure S6. Estimation of the current MPA workforce under alternative assumptions

Each plot shows the predicted total number of FTE as a function of the assumed proportion of unstaffed sites (sites without any personnel). The dotted vertical blue line represents such a proportion in the sampled data. The black point corresponds to the estimate at such a proportion, while the black line represents the FTE estimate for other proportions of unstaffed sites between 0 and 20%. Grey zones capture 95% of simulation estimates. Each column corresponds to a particular simulation scheme shown in Fig. S5 (based on full empirical resampling, on two full parametric fit, and on two empirical-parametric approaches, respectively). Each row corresponds to a different number of total sites to be populated following alternative definitions of what constitutes a site to be populated (top: a single MPA or a set of intersecting MPAs; middle: a single MPA or a set of MPAs overlapping by at least 50%; bottom: a single MPA). The plot framed in orange corresponds to the situation discussed in the main text.

Table S1. Output from likelihood ratio tests (LRTs) comparing models predicting the total number of FTEs. Underlying models are linear mixed-effects models fitted on log(FTE + 0.1). Degrees of freedom are shown but not used within the LRTs which were computed using parametric bootstrap. LRTs compared models including or not the single fixed effect indicated in the column "Predictor" to which a function is sometimes applied to improve the goodness of fit of the models (column "Function"). All models included site IDs as random effects.

Parameter	β	χ^2	df	p	N (resp.)	N (sites)
MPA size						
(Intercept)	0.868	3.904	1	0.055	160	132
log(area_km2)	0.073					
remoteness						
(Intercept)	1.507	0.423	1	0.502	164	136
log(pop_within_100km + 1)	-0.017					
distance from equator						
(Intercept)	1.602	1.373	1	0.247	164	136
abs(latitude)	-0.012					
GDP						
(Intercept)	6.358	7.148	1	0.007	166	138
log(GDP)	-0.481					
continent						
(Intercept) [ref: Africa]	2.213	18.501	5	0.008	166	138
Asia	-0.695					
Europe	-1.274					
Latin America and the Caribbean	-1.492					
Northern America	-0.639					
Oceania	-0.259					

stage of establishment						
(Intercept) [ref: actively managed or implemented]	1.792	12.239	3	0.008	166	138
designated	-1.726					
proposed	-1.343					
unknown	-0.688					
level of protection						
(Intercept) [ref: fully/highly]	1.965	13.130	1	0.002	166	138
other	-1.064					
fully or highly protected						
(Intercept) [ref: FALSE]	0.901	13.130	1	0.002	166	138
TRUE	1.064					
blue park status						
(Intercept) [ref: FALSE]	1.181	8.975	1	0.004	166	138
TRUE	1.377					
level of protection incl. blue park						
(Intercept) [ref: fully/highly (Blue Parks)]	2.554	15.900	2	0.004	166	138
fully/highly (not Blue Parks)	-0.813					
other	-1.652					
IUCN classification						
(Intercept) [ref: Ia]	1.199	11.701	6	0.086	166	138
Ib	-0.702					
II	0.332					
IV	-0.593					

Unknown	0.277					
V	-0.880					
VI	0.789					
designation year						
(Intercept)	-12.886	0.453	1	0.511	152	128
designation_year	0.007					
number of technologies						
(Intercept) [ref: 0]	0.060	50.522	6	0.001	166	138
1	0.812					
2	1.600					
3	1.956					
4	1.990					
5	3.230					
6	1.339					

Table S2. Output from model fits and likelihood ratio tests (LRTs) comparing models predicting the probability for adequacy to reach at least a certain level as a function of: (i) either the personnel number (expressed in FTEs), or (ii) only an intercept. Underlying models are generalized linear models fitted on binary variables (binomial family, link logit). Degrees of freedom are shown but not used within the LRTs which were computed using parametric bootstrap. LRTs compared models including or not the single fixed effect (i.e. log(FTE + 0.1)). The sample size is the same for all models: N_{resp} = 138, N_{sites} = 116.

Parameter	β	χ^2	df	p	N (resp.)
at least somewhat adequate					
(Intercept)	0.053	43.4	1	0.001	138
FTE_log_p	0.963				
at least moderatly adequate					
(Intercept)	-1.088	33.4	1	0.001	138
FTE_log_p	0.766				
at least mostly adequate					
(Intercept)	-2.179	6.5	1	0.008	138
FTE_log_p	0.361				

Table S3. Output from model fits and likelihood ratio tests comparing models predicting the probability for adequacy to reach at least a certain level as a function of: (i) either the personnel number (expressed in FTEs) in interaction with the size of the site, or (ii) only the personnel number. Underlying models are generalized linear models fitted on binary variables (binomial family, link logit). Degrees of freedom are shown but not used within LRTs which were computed using parametric bootstrap. LRTs compared models including, as fixed effects, either log(FTE + 0.1)+log(area + 0.1)+log(FTE + 0.1):log(area + 0.1), or only log(FTE + 0.1). The sample size is the same for all models: N_{resp} = 135, N_{sites} = 113.

Parameter	β	χ²	df	p	N (resp.)
at least somewhat adequate					
(Intercept)	-0.343	0.981	2	0.618	135
FTE_log_p	1.159				
area_log_p	0.063				
FTE_log_p:area_log_p	-0.033				
at least moderately adequate					
(Intercept)	-1.635	1.241	2	0.539	135
FTE_log_p	0.945				
area_log_p	0.079				
FTE_log_p:area_log_p	-0.028				
at least mostly adequate					
(Intercept)	-2.300	0.104	2	0.958	135
FTE_log_p	0.449				
area_log_p	0.009				
FTE_log_p:area_log_p	-0.010				