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Contributed Paper

Evaluating the social and ecological effectiveness of partially protected marine areas

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Abstract: Marine protected areas (MPAs) are a primary tool for the stewardship, conservation, and restoration of marine ecosystems, yet 69% of global MPAs are only partially protected (i.e., are open to some form of fishing). Although fully protected areas have well-documented outcomes, including increased fish diversity and biomass, the effectiveness of partially protected areas is contested. Partially protected areas may provide benefits in some contexts and may be warranted for social reasons, yet social outcomes often depend on MPAs achieving their ecological goals to distinguish them from open areas and justify the cost of protection. We assessed the social perceptions and ecological effectiveness of 18 partially protected areas and 19 fully protected areas compared with 19 open areas along 7000 km of coast of southern Australia. We used mixed methods, gathering data via semistructured interviews, site surveys, and Reef Life (underwater visual census) surveys. We analyzed qualitative data in accordance with grounded theory and quantitative data with multivariate and univariate linear mixed-effects models. We found no social or ecological benefits for partially protected areas relative to open areas in our study. Partially protected areas had no more fish, invertebrates, or algae than open areas; were poorly understood by coastal users; were not more attractive than open areas; and were not perceived to have better marine life than open areas. These findings provide an important counterpoint to some large-scale meta-analyses that conclude partially protected areas can be ecologically effective but that draw this conclusion based on narrower measures. We argue that partially protected areas act as red herrings in marine conservation because they create an illusion of protection and consume scarce conservation resources yet provide little or no social or ecological gain over open areas. Fully protected areas, by contrast, have more fish species and biomass and are well understood, supported, and valued by the public. They are perceived to have better marine life and be improving over time in keeping with actual ecological results. Conservation outcomes can be improved by upgrading partially protected areas to higher levels of protection including conversion to fully protected areas.

Keywords: environmental stewardship, fully protected areas, marine protected areas, mixed methods, partially protected areas, social–ecological systems

Análisis de la Efectividad Social y Ecológica de las Áreas Marinas Parcialmente Protegidas

Resumen: Las áreas marinas protegidas (AMPs) son una herramienta importante para la administración, conservación y restauración de los ecosistemas marinos; sin embargo, el 69% de las AMPs mundiales solamente están parcialmente protegidas (es decir, están abiertas a alguna forma de pesca). Aunque las áreas completamente protegidas tienen resultados bien documentados, incluyendo el incremento en la diversidad de peces y la biomasa, la efectividad de las áreas parcialmente protegidas está en disputa. Puede que las áreas parcialmente protegidas se justifiquen por razones sociales, aunque los resultados sociales con frecuencia dependen de que las AMPs alcancen sus metas ecológicas para distinguirlas de las áreas abiertas y justificar el costo de la protección. Analizamos las percepciones sociales y la efectividad ecológica de 18 áreas parcialmente protegidas y 19 áreas completamente protegidas a lo largo de 7000 km de costa en el sur de Australia. Usamos métodos mixtos, recopilando información por medio de entrevistas semiestructuradas, encuestas en sitio y censos Reef Life (censos visuales submarinos).

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__Article impact statement__: Partially protected areas create an illusion of protection and consume conservation resources for little or no social–ecological gain.

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Analizamos los datos cualitativos de acuerdo con la teoría fundamentada y los datos cuantitativos con modelos lineales de efectos mixtos multivariados y univariados. No encontramos beneficios sociales o ecológicos para las áreas parcialmente protegidas en relación con las áreas abiertas en nuestro estudio. Las áreas parcialmente protegidas no tuvieron más peces, invertebrados o algas que las áreas abiertas; los usuarios de la costa tenían poco entendimiento de ellas; no eran más atractivas que las áreas abiertas; y no eran percibidas como albergues de mejor vida marina que las áreas abiertas. Estos hallazgos proporcionan un contrapunto importante a algunos metaanálisis a gran escala que concluyen que las áreas parcialmente protegidas pueden ser ecológicamente efectivas, pero llegan a esta conclusión con base en medidas más reducidas. Discutimos que las áreas parcialmente protegidas funcionan como pistas falsas para la conservación marina pues crean una ilusión de estar protegidas y consumen pocos recursos para la conservación, pero proporcionan poca o ninguna ganancia ecológica o social en comparación con las áreas abiertas. Las áreas completamente protegidas, al contrario, tienen más especies de peces y biomasa y están bien comprendidas, respaldadas y valoradas por el público. Este tipo de AMPs son percibidas como albergues de mejor vida marina y como en constante mejora con el tiempo al mantenerse en regla con los resultados ecológicos actuales. Los resultados de la conservación pueden mejorarse si se eleva a las áreas parcialmente protegidas a niveles más altos de protección incluyendo la conversión a áreas completamente protegidas.

Palabras Clave: administración ambiental, áreas marinas protegidas, áreas completamente protegidas, áreas parcialmente protegidas, métodos mixtos, sistemas socioecológicos

【摘要】: 海洋保护区 (MPAs) 是管理、保护和恢复海洋生态系统的主要工具, 然而, 全球69%的海洋保护区只受到部分保护 (即开放某种形式的捕捞) 。虽然完全保护的保护区的保护成果已经得到充分报道, 包括鱼类多样性和生物量增加, 但部分保护的保护区的有效性仍存在争议。部分保护的保护区的建立可能是出于社会原因, 但其社会结果往往取决于这些海洋保护区是否能实现其生态目标, 以证明其有别于开放海域, 且投入的保护成本具有意义。本研究评估了18 个部分保护的保护区和19 个完全保护的保护区的社会认知和生态效益, 并将它们与南澳大利亚 7000 公里海岸线上的19个开放海域进行了比较。我们采用半结构化访谈、现场调查和 Reef Life 调查报告 (水下视觉调查) 的混合方法收集了数据, 并依照实地理论分析了定性数据, 用多变量和单变量线性混合效应模型分析了定量数据。结果发现, 本研究中的部分保护的保护区相对于开放海域没有明显的社会或生态效益。部分保护的保护区与开放海域相比不具有更多的鱼类、无脊椎动物或藻类;沿海住户对其知之甚少;它没有比开放海域更引人注意;公众也不认为那里有更好的海洋生物。以上发现为一些大尺度荟萃分析得出的结论提供了对比, 这些研究认为部分保护的保护区具有生态有效性, 但仅基于有限的指标得出结论。我们认为, 部分保护的保护区在海洋保护中起到了转移注意力的作用, 因为它们制造了一种保护的假象, 消耗了稀缺的保护资源, 但与开放海域相比, 却很少或根本没有提供社会或生态利益。相比之下, 完全受保护的地区有更多的鱼类物种和生物量, 而且得到了公众很好的认识、支持和重视。它们被认为拥有更好的海洋生物, 且随着时间的推移不断改善, 这与实际的生态结果一致。我们提出, 对部分保护的保护区进行更高级别的保护, 包括转为完全保护区, 可以改善保护成果。**【翻译:胡怡思;审校:聂永刚】**

关键词: 部分保护的保护区, 完全保护区, 海洋保护区, 社会生态系统, 环境管理, 混合方法

Introduction

No area in the ocean is untouched by human activity, and over 40% of the marine environment is strongly affected by multiple stressors, often with cumulative impacts (Halpern et al. 2015). Marine protected areas (MPAs) are a primary tool for stewardship, restoration, and conservation of marine ecosystems, and much research has been dedicated to understanding the factors that contribute to their effectiveness (Ballantine 2014). Although substantial areas of the ocean have been assigned to MPAs, many of these are ineffective, raising concerns that the illusion of conservation has been created (Costello & Ballantine 2015; Edgar 2017).

Poor design and management have been highlighted as key issues in MPA effectiveness, including factors such as size, level of protection, management, and enforcement (Edgar 2017). Sanctuary, no-take or fully protected areas (FPAs) (Zupan et al. 2018*a*) are considered the gold standard for ecological effectiveness (Costello & Ballantine 2015; Sala & Giakoumi 2017), yet they comprise just 2.46% of the area of the world's oceans (UNEP-WCMC and IUCN, 2020). Partially protected areas (PPAs), which allow the use of some fishing methods but not others (Zupan et al. 2018*a*), comprise 5.45% of the world's oceans and the majority (69%) of MPA area (UNEP-WCMC and IUCN 2020).

Fully protected areas may be categorized as International Union for Conservation of Nature (IUCN) categories Ia, Ib, II, or III (Day et al. 2012). Partially protected areas may be categorized as IUCN IV, provided fishing can be managed in a way that is compatible with MPA objectives, or V or VI if fishing is sustainable (Day et al. 2012). Commercial or industrial fishing is incompatible with all types of MPAs (IUCN WCPA, 2018). Although new MPAs continue to be declared, there is a declining emphasis on FPAs (Costello & Ballantine 2015). Furthermore, recent studies of both terrestrial and marine protected areas report an increasing trend toward downgrading, downsizing, and degazetting protected areas (PADDD), particularly in the last two decades (Ritchie et al. 2013; Kroner et al. 2019).

Despite the seeming popularity of PPAs among decision makers, their effectiveness is variable and a subject of debate (e.g., Costello & Ballantine 2015; Edgar 2017; Gill et al. 2017). One meta-analysis shows no significant ecological effects of PPAs, although nonsignificant positive effects were detected (Lester & Halpern 2008). Another meta-analysis (Sciberras et al. 2015) shows some ecological benefits of PPAs over open areas, but only for fishing-targeted species, and benefits were significantly less in PPAs than FPAs. A third meta-analysis shows varying degrees of ecological effectiveness, depending on the level of partial protection (Zupan et al. 2018*a*), although many of the studies within this analysis considered only a narrow set of response parameters, such as one or a few target species rather than overall community biodiversity or biomass. Many PPAs have been in place for decades and have had no ecological benefit relative to FPAs and limited to no benefits relative to open areas (e.g., Turnbull et al. 2018; Sala et al. 2018). It is clear that further research on the effectiveness of PPAs is needed to improve conservation outcomes (Edgar 2017).

Partially protected areas also appear to offer little or no financial cost advantage over FPAs. A worldwide study (Balmford et al. 2004) shows that FPAs are slightly more costly per unit area than PPAs, but the level of protection is not an important predictor of MPA cost compared with other factors. A subsequent study modeling the protection of Australia's Coral Sea shows that a large MPA with a blend of partial and full protection is more costly than a simpler FPA (Ban et al. 2011).

Social factors are also key considerations in the effectiveness of MPAs, including stakeholder engagement, leadership, and management (Ballantine 2014), yet social–ecological studies of MPAs are rare (Hargreaves-Allen et al. 2017; Davies et al. 2018; Brueckner-Irwin et al. 2019). Partially protected areas may be warranted for socioeconomic or political reasons (Sciberras et al. 2015), and this inherently entails a trade-off between political, social, and ecological goals (Sala & Giakoumi 2017; Davies et al. 2018). Partially protected areas may improve some social values because they allow more recreational activities than FPAs, yet they compromise on values that depend on biodiversity and abundance (e.g., observing wildlife). Although protected areas may be valued and even informally enforced by the local community, potentially improving their ecological effectiveness (Rife et al. 2013; Turnbull et al. 2018; Brueckner-Irwin et al. 2019), it is unclear whether this applies in PPAs. Partially protected areas have more complex regulations than FPAs because some extraction activities are permitted but not others, so they may be more difficult to understand, comply with, and enforce (Roberts et al. 2020). Given these complexities and compromises, work is needed to reveal the value and effectiveness of PPAs as a conservation measure in the social–ecological system.

We investigated the marine ecological and human communities of MPAs along the Great Southern Reef, which spans 5 states along the southern half of the Australian continent (Bennett et al. 2016). As is the case globally (Sala & Giakoumi 2017), the primary stated purpose of MPAs in all five states is broadly ecological: the conservation and protection of biological diversity and ecological processes (Appendix S1). Secondary purposes are largely social; they include the sustainable use of natural resources, cultural values including enjoyment, appreciation, learning, research, and indigenous uses (Appendix S1). Support for Australia's MPAs is high, including among people who fish (Martin et al. 2016; Navarro et al. 2018), yet the complex factors that motivate support, compliance, understanding (and misunderstanding), and the social and ecological values of these MPAs warrant further investigation (Clark & Johnston 2017; Davies et al. 2018).

We assessed both the social and ecological attributes of open areas, PPAs, and FPAs in roughly equal proportion. Our goal was to determine how PPAs and FPAs are used, understood, and perceived compared to open areas, and how protection relates to the ecological status of their broad fish, invertebrate, and algal communities.

Methods

Our research took place over 56 sites spanning 7000 km of coastline along Australia's Great Southern Reef (Fig. 1). Our sites were distributed among 5 Australian States (jurisdictions) with roughly even distribution across protection levels; 19 sites were FPAs, 18 sites were PPAs, and 19 sites were open areas (outside MPAs). Partially protected areas were all open to fishing at 3 levels of regulation; 7 were highly protected, 7 were moderately protected, and 4 were very weakly protected (Appendix S4) (Horta e Costa et al. 2016). Our study covered 20 MPAs, ranging in protection level from IUCN Ia to VI, with an average age of 20 years (SD 10.9) and an average size of 280 km^2 (SD 725) (Appendix S3). Open areas were selected for comparison based on the range of exposures, substrate (rocky reef, and beach), and development levels where possible (Appendix S4).

Because the goals of MPAs are both ecological and social, we used mixed methods. We conducted 190 structured observation social surveys and 439 semistructured interviews to gather data on human usage, perceptions, and values and analyzed data on 625 underwater visual census Reef Life Surveys to draw conclusions on

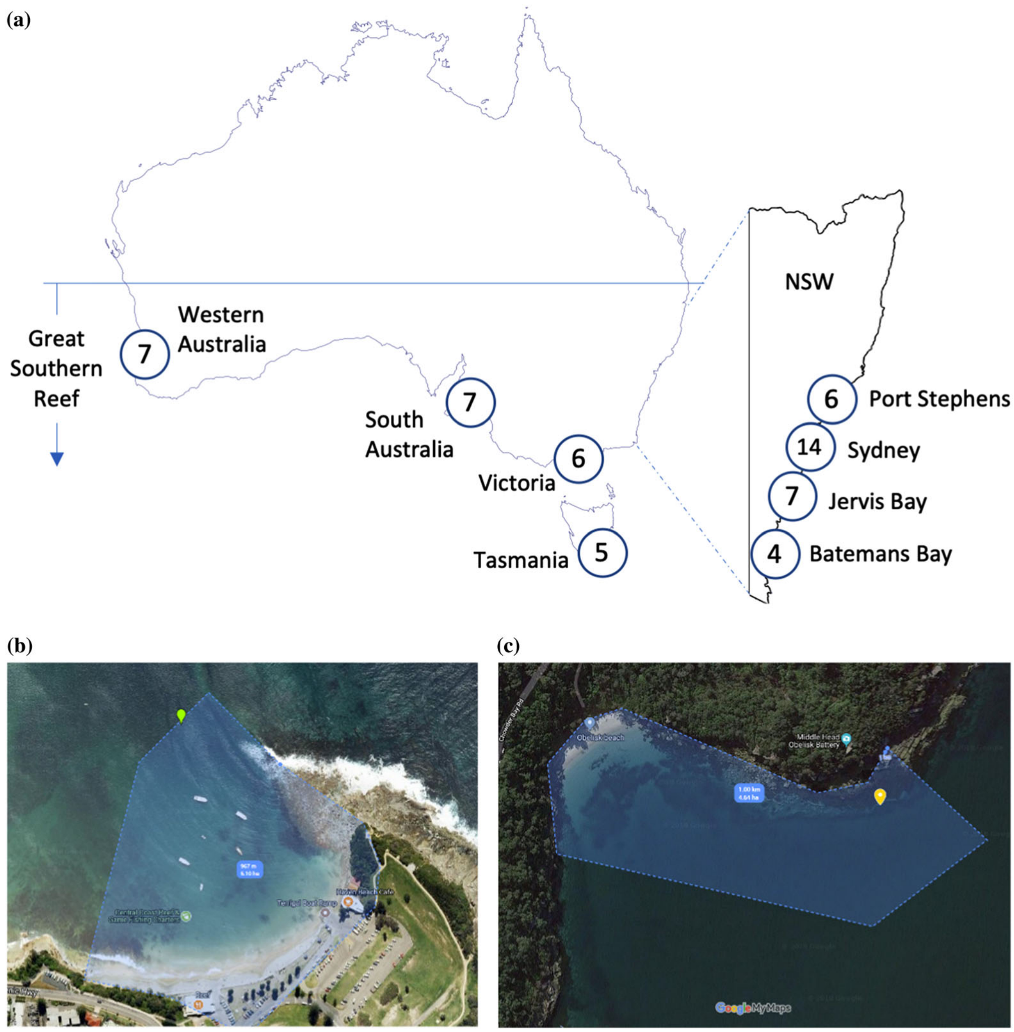


Figure 1. (a) Location of study sites around Australia's Great Southern Reef (numbers, number of sites surveyed in each region), (b) study area at Terrigal Haven (developed site), and (c) study area at Middle Head (undeveloped site) (pins, Reef Life Survey locations).

marine communities (RLS 2016). In the social aspects of our study, we followed grounded theory, identifying and developing concepts via structured analysis and inductive reasoning over the course of our study (Glaser et al. 1968). We used purposive sampling to achieve a representative sample of coastal users and proceeded to the point of theoretical saturation, which was achieved at participant 358 out of 439 (Bryman 2016). Qualitative social data were coded both in situ (e.g., self-identification as local) and later in vivo (e.g., initial and thematic coding of motivations and values). Survey guides are in Appendix S2).

Species richness, abundance (density), and biomass were selected as our ecological indicators because they represent the broad goals of MPAs and are used in similar studies (e.g., Lester & Halpern 2008; Edgar et al. 2014). We used both multivariate and univariate methods to analyze relationships between and among social and ecological variables, and qualitative data analysis to examine human factors in more detail.

We followed human ethical guidelines of the University of New South Wales under permit HC180044. For a full description of our methods, see Appendix S2.

Results

The PPAs were no better than open areas for any of our measured social or ecological factors based on the stated goals of the MPAs in our study. The FPAs had significantly more fish richness and biomass and greater human understanding of their purpose than open areas. They also were more positively perceived and assigned higher value than open areas (Fig. 2). Significance and effect sizes for all results relating to partial and FPAs are in Appendix S7.

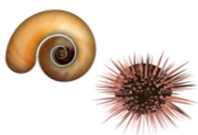
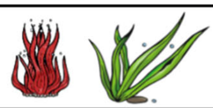
		PPA	FPA
Ecological			
	Fish diversity (species richness)		↑
	Fish biomass		↑
	Large (20+ cm) fish biomass		↑
	Mobile macro-invertebrate diversity (sp. richness)		
	Mobile macro-invertebrate abundance	↓	↓
	Mobile macro-invert abundance (excl. urchins)		
	Sessile invertebrate diversity (CATAMI)	↓	
	Sessile invertebrate cover	↓	
	Algal diversity (CATAMI)		
	Algal cover		
Social			
	Human usage community		↔
	Attraction to ecological values		↑
	Attraction to protection values		↑
	Understanding of MPA and level of protection	↓	↑
	Perception that marine life is better at site		↑
	Perception that marine life is improving over time		↑

Figure 2. Summary of results of multivariate and univariate analysis for partially protected areas (PPAs) and fully protected areas (FPAs) compared with open areas (blank cell, no significant difference between protected and open areas; up arrow, positive significant relationship [e.g., more fish diversity and biomass]; down arrow, negative significant relationship; left and right arrow combined, significantly different community with more of some users and fewer of others; CATAMI, Collaborative and Automated Tools for Analysis of Marine Imagery [Althaus et al. 2013]; p *< 0.05, benchmark for significance based on permutational multivariate analysis of variance for community results and mixed-effects linear regression for other results). The* p*-values and effect sizes are in Appendix S7.*

Social Surveys

Of 56 sites, the busiest had a mean density of 31.9 people/ha and the quietest had 0.13 people/ha (SD 5.02) (Appendix S4). Fully protected areas had 2.0 times as many SCUBA divers, 3.5 times as many snorkelers, almost no people fishing, and 0.2 times as many people using watercraft (including boating) compared to open areas ($p = 0.012$) (Appendix S5). There was no significant difference between human usage communities in PPAs verses open areas ($p = 0.837$), including no difference in the density of people fishing ($p = 0.305$).

Almost half of participants who expressed a view of protection in PPAs (42%) incorrectly believed that fish were protected at their site. Most participants in FPAs (91%) correctly perceived fish as protected (Fig. 3a). Both of these results were significantly higher than the perception of fish protection in open areas ($p_{PPA} = 0.006$ and $p_{FPA} < 0.001$). Belief that a participant was in an MPA (regardless of whether they were actually in an MPA) was also significantly related to the belief that fish were protected ($p < 0.001$). Participants appeared to get cues regarding fish protection from the presence of compliance signage ($p < 0.001$) and the presence or absence of people fishing ($p < 0.001$).

Most people in FPAs knew they were in one (79%), contrasting with relatively few people correctly identifying that they were in a PPA (12%, $p < 0.001$) (Fig. 3b). The remaining 88% in PPAs were split between those who overestimated the level of protection (i.e., thought they were in an FPA [40%]), those who underestimated the level of protection (i.e., thought they were in an open area [23%]), and those who responded with “don’t

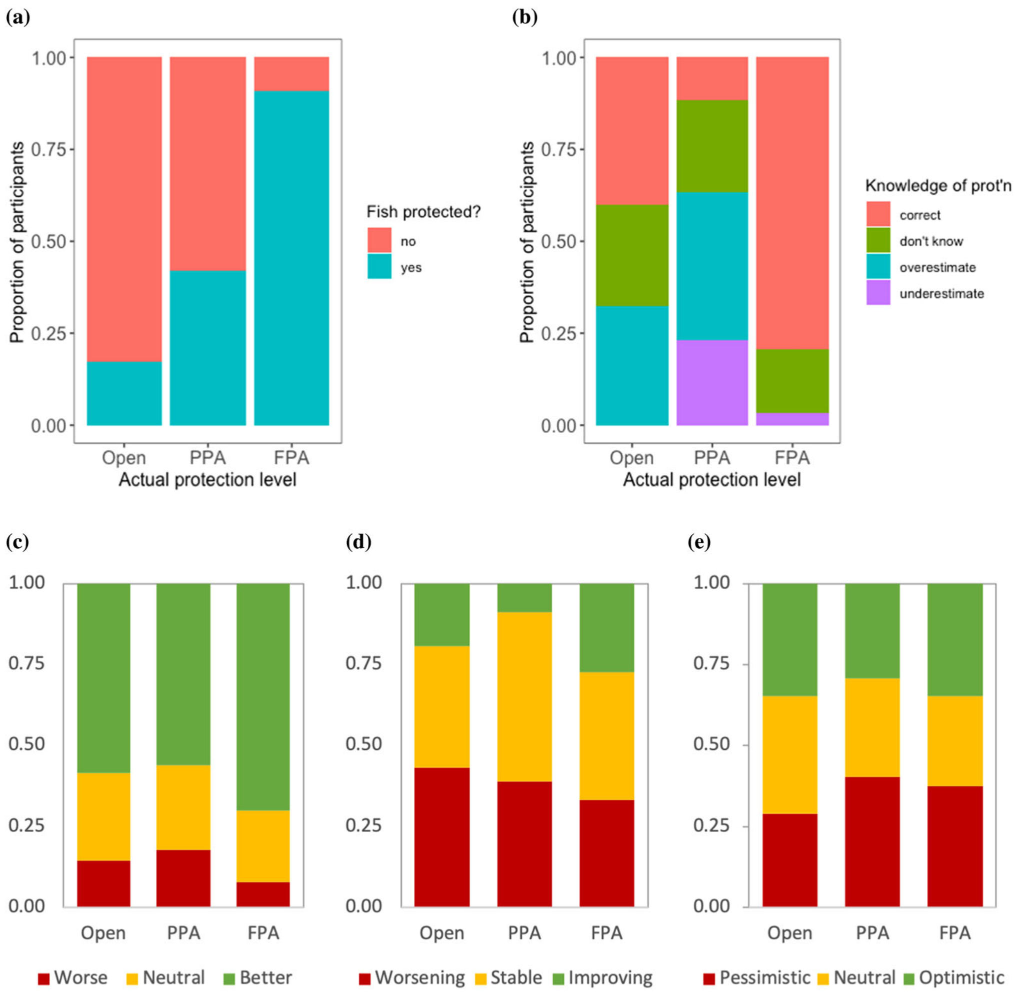


Figure 3. Perceptions of coastal users of protection and marine life by protection level (open, unprotected areas; PPA, partial protected areas; FPA, fully protected areas): (a) proportion of participants who expressed a view on fish protection at the site; (b) proportion of participants who correctly identified whether they were in a partial or full PA; (c) perceptions of how good the marine life is at a site compared with other sites in the region; (d) perceived changes in marine life over time; and (e) perceptions of what participants expect marine life at the site to be like 5 years in the future. Frequency distributions of responses over $n = 439$ *participants*

know" (25%). The density of signage tended to increase the understanding of MPA status, but this relationship was not significant ($p = 0.071$).

Support for MPAs in which fishing was restricted was high overall (92% support, 2% don't support, and 6% neutral or unsure). Support among people who said they fished at their site was similar (91% support, 1% don't support, and 8% neutral or unsure). People in FPAs were significantly more likely to support MPAs that restricted fishing ($p = 0.015$), primarily motivated by the need to address overfishing and fishing pressure; conserve fish diversity, abundance, and health; protect and preserve marine life; enable recovery and restoration of fish stocks; and for ethical considerations (e.g., it is the right thing to do). Disagreement with MPAs centered on the beliefs that existing rules—size and bag limits—were adequate and human pressures were low and that there is the need for freedom and recreation, particularly for children.

People in FPAs were significantly attracted to their ecological values ($p = 0.01$) and the protection values of the MPA ($p = 0.009$), whereas the factors attracting people to PPAs were not significantly different from those in open areas ($p = 0.64$ and 0.14, respectively). The most common ecological values attracting people to FPAs were more marine life, nature, biodiversity, naturalness or pristineness, the ocean, and the environment. The most common protection or management values were the presence of full protection, science or research value of protection, and avoiding user conflict due to zoning.

The most frequently mentioned ecological value was the presence of fish, including abundance, richness, protection, health, replenishment, catching, and concern over declines. People were generally optimistic about the quality of marine life at their site (Fig. 3c) and perceived marine life to be better when there were more actual fish species ($p < 0.001$) and higher sessile (invertebrate and algal) diversity ($p = 0.004$). Wet users (i.e., those with direct in-water experience of marine life in its habitat such as swimmers, snorkelers, and divers) perceived better marine life in FPAs compared to open areas ($p = 0.017$), but no difference in marine life between PPAs and open areas ($p = 0.128$). Signage did not significantly influence people's perceptions of marine life.

Overall, people perceived stable or worsening marine life at their site through time (Fig. 3d). Least improvement was perceived in PPAs (although not significant), whereas significantly more improvement was perceived in FPAs by wet users ($p = 0.017$). Signage did not significantly affect these results. Perceived changes over time were mostly founded on observing impacts or threats and changes in ecological values including fish, algae or seagrass, marine mammals, birds, and crustaceans. The main perceived threats were overfishing, pollution, overpopulation, development, erosion (often driven by climate change), and illegal fishing.

When asked to consider 5 years into the future, people were more optimistic than would be justified by history (Figs. 3d & 3e), and there was no significant difference in optimism or pessimism between protection levels ($p_{\mathrm{PPA}} = 0.348$ and $p_{\mathrm{FPA}} = 0.710$). Optimists spoke mostly of management and stewardship, specifically caring for or looking after a place, education of users, and the presence of MPAs. Pessimists spoke mostly of threats into the future, specifically human overpopulation, pollution, fishing pressure, climate change, mismanagement, and reductions in protection (PADDD).

Many (27% of participants) reported observing noncompliance at their site; 10% reported seeing it once, 12% sometimes, and 5% often. Observed noncompliance did not vary significantly between MPAs and open areas ($p_{\mathrm{PPA}} = 0.908$ and $p_{\mathrm{FPA}} = 0.163$), although almost one-third (30%) of all people in FPAs reported seeing illegal fishing. Other forms of noncompliance included illegally collecting invertebrates (observed by 4.6% of people), keeping undersize fish (3.9%), exceeding bag limits (3.4%), and illegal spearfishing (2.5%). Formal enforcement activity levels were low. During over 300 hours in the field, we observed enforcement activities on just 3 occasions: 2 in FPAs and 1 in a PPA.

Ecological Surveys

Fish species richness and biomass of all fish and large (>20 cm) fish were higher in FPAs ($p = 0.023$, 0.023, and 0.05, respectively), and biomass was lower, but not significantly so, in PPAs (Figs. 4a & 4b). There were 1.3 times more fish species, 2.5 times more fish biomass, and 3.5 times more large (>20 cm) fish biomass in FPAs compared to open areas. Further analysis showed this could be partly explained by fisher density (modeled separately because it was correlated with protection level), which had a significant negative relationship with fish biomass ($p = 0.028$) (Fig. 4f).

Of the top 10 fish species that explained biomass differences, 7 (70%) were fished species that had higher biomass in FPAs than in open areas (Appendix S6). The proportion of fished species in the top 10 explanatory species was markedly higher than the proportion of fished species in the overall data set (20%).

Our initial analysis showed significantly less mobile macroinvertebrate abundance (urchins, sea stars, shells, etc.) in both FPAs and PPAs compared to open areas ($p = 0.038$ and 0.028, respectively), and this was due to low levels of barren-forming urchins (*Centrostephanus rodgersii* and *Heliocidaris erythrogramma*), which were approximately half as abundant in MPAs compared to open areas (Fig. 4c & Appendix S6). There was significantly less sessile invertebrate cover and diversity (sponges, soft corals, ascidians, etc.) in PPAs compared to open areas ($p = 0.003$ for both) (Figs. 4d & 4e), but no significant difference in sessile invertebrates between FPAs and open areas (Fig. 2 & Appendix S7). There was no significant difference in algal cover or diversity among FPAs, PPAs, and open areas (Fig. 2 & Appendix S7)

Discussion

Along the 7000 km coastline in our study, FPAs had more fish species and biomass, were better understood by people, aligned better with the expectations of the public than PPAs, were more attractive to most users, and perceived to have better marine life than open areas. Partially protected areas, despite being the most common type of MPA (exceeding the area of FPAs by more than 2:1 globally and 3:1 in Australia), were no better than open areas for any of our social or ecological indicators. Partially protected areas give the impression of protection while consuming scarce conservation resources, so we argue that they are red herrings in marine conservation.

In popular culture, a red herring is a clue or piece of information that is misleading or distracting (Oxford University Press 2019). We regard PPAs as misleading for several reasons. First, they create the illusion that fish are effectively protected (Figure 3a). Partial protection is poorly understood; just 1 in 8 participants in PPAs (12%) knew they were in one, with 3 times as many people (40%) mistakenly believing they were in an FPA. People in our study appeared to assume or trust that the presence of an MPA has a positive ecological effect, yet in PPAs we could find no such effects.

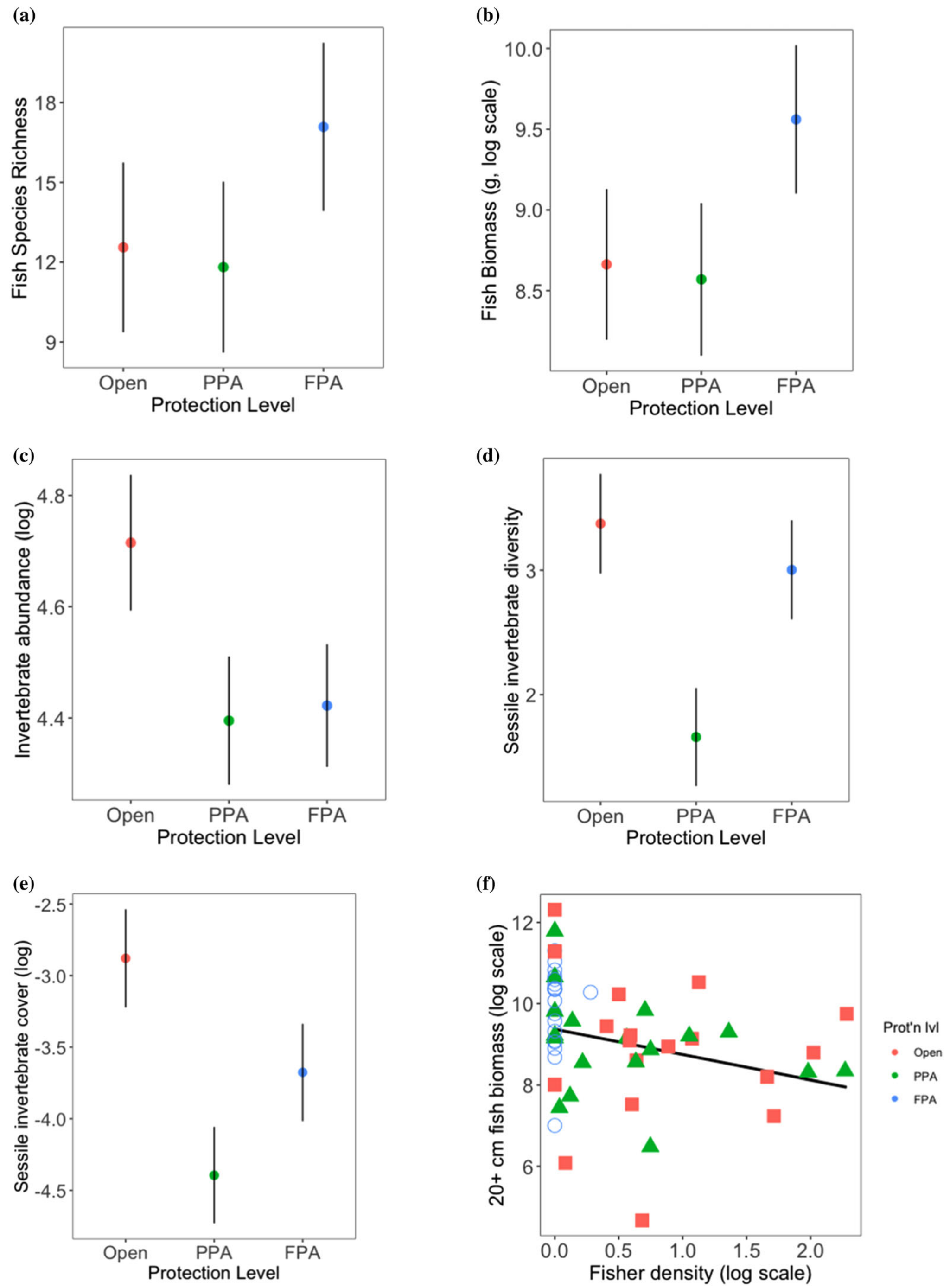


Figure 4. Comparison of open sites, partially protected areas (PPAs) and fully protected areas (FPAs) relative to significant factors: (a) species richness of all fish, (b) biomass of all fish, (c) abundance of mobile macroinvertebrates, (d and e) diversity and cover of sessile invertebrates based on CATAMI classification (Collaborative and Automated Tools for Analysis of Marine Imagery [Althaus et al. 2013]), and (f) significant negative relationship between fisher density and large fish biomass (regression line from mixed-effect model; bars, SE).

We regard PPAs as a distraction primarily due to their opportunity costs. MPAs are financially costly in terms of design, planning, management, and enforcement resources (Rife et al. 2013), and PPAs offer no clear cost advantage over FPAs. In a world of limited conservation budgets, spending money with at best questionable or, in the case of our study, no detectable ecological or social benefit represents a waste of resources that could be assigned to more effective protection. Partially protected areas also have a spatial opportunity cost. Any given jurisdiction, such as state or commonwealth waters, is of finite area and so consuming an area with PPAs effectively prevents the implementation of real protection in those same areas. This would not be the case if PPAs were seen as stepping stones toward FPAs; however, the extensive and growing PADDD phenomenon indicates that this is not the case in many jurisdictions (Kroner et al. 2019).

The misleading and diversionary nature of PPAs in our study is perpetuated at an institutional or policy level by their inclusion in a commonly used conservation performance indicator—percentage of jurisdiction under protection. Australia reports 36% of waters in MPAs (Parks Australia 2020), yet three-quarters of this protected area appear to have little or no social or ecological function, at least in the Great Southern Reef. In effect, these are the very paper parks that other researchers caution against (Rife et al. 2013; Costello & Ballantine 2015); yet, they are perceived as contributing to Australia's marine conservation goals (Appendix S1).

We do not contend that PPAs cannot be effective in all circumstances. Partially protected areas may play a role as part of a wider management framework, for example, when placed adjacent to FPAs (Zupan et al. 2018a; Kelleher 1999). Partially protected areas that explicitly target social outcomes, such as enabling traditional fishing practices, or narrow ecological outcomes, such as protection of certain species or critical habitat, may succeed in achieving these goals (Cinner et al. 2020). It is noteworthy, however, that the PPAs in our study do not explicitly limit themselves to such specific goals. Partially protected areas may also favor one stakeholder group over another, for example, protected areas that ban only commercial fishing may benefit recreational fishers. However, such redistributions of social benefit appear to occur with no overall improvement in broad ecological goals, such as biodiversity or biomass, in our study.

Misconceptions about the effectiveness of PPAs may be perpetuated by results of studies referenced as evidence of effectiveness that are based on assessment criteria that are narrower than the overall goals of MPAs (Edgar 2011). Marine protected areas generally aim to achieve broad, ecosystem-wide outcomes (Edgar 2011; Sala & Giakoumi 2017) (Appendix S1), yet prior studies draw conclusions on the basis of 1 or a few species or subsets, such as only species targeted by fishers (Zupan et al. 2018a; Sciberras et al. 2015). Partially protected areas that allow one fishing gear yet ban another may shift fishing pressure between fished areas and toward people who use the allowed gear and who are attracted to the reduced competition over space and fish (Zupan et al. 2018*b*; Lester & Halpern 2008). Partially protected areas may therefore merely trade 1 or more species or pressure for another. This is supported by our finding that despite some fishing activities being prohibited in PPAs, they show no significant improvement in any of our broad ecological indicators (Fig. 2).

Partially protected areas may appear to be an attractive compromise because they allow large areas of ocean to be declared protected while allowing the public to continue enjoying a range of extractive pursuits. This, however, represents another form of conservation red herring. Marine protected areas work by removing or significantly reducing human pressures—mostly fishing pressure—from an area (Edgar et al. 2017). This is supported by our finding of the significant negative relationship between fish biomass and fisher density (Fig. 4f) and the proportion of fished species explaining significant biomass differences (Appendix S6). Failure to remove this pressure, by declaring an area as protected without substantially reducing or eliminating fishing, must therefore result in ineffective protection (Fig. 2 & Appendix S4) (Zupan et al. 2018*b*). Ironically, the failure of PPAs to deliver ecological outcomes appears to lead to the failure of the desired social outcomes. More sustainable social use of resources, scientific research, education, appreciation, and enjoyment largely rely on MPAs performing their ecological functions in order to distinguish them from open areas and to justify the cost of protection.

The desire to achieve a combination of political, social, and ecological goals may be driving the proliferation of PPAs (Sciberras et al. 2015), but it has been argued that such considerations should not take priority over ecological effectiveness (Boonzaier & Pauly 2016). Most of the PPAs in our study allow commercial fishing, even though industrial-level extraction of resources is incompatible with MPAs (Day et al. 2019) (Appendix S3). Commercial fishing in MPAs is widespread in other jurisdictions (Horta e Costa et al. 2016; Sala et al. 2018), for example, in the majority of Canadian MPAs (Robb et al. 2011). One recent study of MPAs in the Mediterranean Sea shows that 95% of the area under protection lacks adequate regulations to conserve biodiversity and ocean health (Claudet et al. 2020). With increasing global pressure to protect more of our oceans, driven in part by the World Conservation Congress goal of 30% of the oceans free from extractive activities by 2030, such anomalies must be addressed if real conservation outcomes are to be achieved (Sala et al. 2018).

We detected more fish and fewer urchins in FPAs, possibly due to trophic cascade effects, as found in other studies (Edgar et al. 2017). Our finding of fewer invertebrates, but not more fish, in PPAs may be the result of small increases in fish numbers that were undetectable in our analyses yet sufficient to affect invertebrate communities. This result may also be an artifact of the selective placement of MPAs, which may be located to achieve coverage of certain ecological features, such as habitat (Kelleher 1999). We were unable to separate such effects in our results due to the lack of pre-MPA establishment baseline data.

Our finding that coastal users broadly support MPAs that restrict fishing (92% of participants), with similar support among people who fish (91%), is generally in keeping with the results of other studies (Martin et al. 2016; Navarro et al. 2018; McNeill et al. 2019). Even though McNeill et al. (2019) focused on the opposition of specialized fishers to FPAs, this opposition is reported by a minority, with the majority of fishers (around 75%) in support of FPAs and over 50% strongly in favor of them. We found even higher levels of support, possibly due to our sampling, which included a broad sample of all coastal users and did not target specific user segments, such as people at boat ramps (Navarro et al. 2018), nor rely on internet surveys that cannot be considered representative (McNeill et al. 2019). Almost three-quarters of people who fish also undertake other activities, such as swimming and snorkeling, and this may explain the negligible difference in support among all users and people who fish in our study.

Furthermore, our questions explicitly tested the primary human-use distinction between PPAs and FPAs along the Great Southern Reef—the former allow fishing, whereas the latter restrict it—rather than using potentially confusing, jurisdiction-specific language such as *sanctuary* or *no take*. We believe that because MPAs are generally implemented for the benefit of all users rather than specific interest groups in our study (Appendix S1), our research is an accurate reflection of the values and support of stakeholder communities that are affected by and benefit from MPAs.

We found people were often knowledgeable about marine life. Their perceptions of the relative quality of marine life were significantly related to actual fish species richness and sessile (invertebrate and algal) diversity. This indicates coastal users have the ability to evaluate and report conditions of marine life. In-water users (snorkelers, divers, and swimmers) also accurately reported better marine life in FPAs compared to other areas and observed positive changes over time that were not observed in PPAs. It appears that people's perceptions can be a useful indicator of what is happening to marine life in an area, particularly if they experience marine life directly (Uyarra et al. 2009). Reinforcing this, we found knowledge of marine life was significantly higher in locals, those with longer experience with the site, those who came to the site explicitly for its marine life, and those who snorkeled, scuba dived, and line and spear fished.

Signage played a significant role in the perception of whether fish were protected and appeared to influence understanding of MPA status (although the latter was not significant). Although 4 PPAs had no compliance signage at all, only 1 FPA lacked compliance signage (Appendix S4). We would expect that more compliance-related signage may improve awareness and understanding of PPAs, although this may be countered by their higher levels of regulation complexity relative to FPAs (Appendix S4). High stewardship individuals ("uber stewards") may improve awareness, and possibly therefore the effectiveness of signage, through informal enforcement and education, particularly through their extended social networks (Turnbull et al. 2020). Further research is warranted regarding the relationship among signage, stewardship, and awareness of regulations.

Marine protected area effectiveness is driven in part by compliance and enforcement (Rife et al. 2013). Even though we recorded observed enforcement events in our surveys, these events were not frequent enough to generate significant results. Recent studies, however, report very high levels of poaching in 1 FPA and the resulting need for higher prioritization of enforcement resources (Harasti et al. 2019). We directly observed noncompliance events, such as fishing in FPAs on 7% of our site surveys, and 30% of participants reported seeing such events at some time. This indicates that MPA performance may be improved by allocating more resources to enforcement and prioritizing resources between PPAs and FPAs in such a way as to maximize conservation outcomes.

The broad geographic and social–ecological scope of our study necessitated a focus on key factors that we selected based on the stated goals of MPAs. Other social factors, such as impact on livelihoods, satisfaction with MPAs, and equity of access, warrant further investigation, as do other contexts, such as geographies and different levels of economic development. Partially protected areas may for example confer fisheries benefits (Zupan et al. 2018a, Cinner et al. 2020), and may be effective in traditional management settings (McClanahan et al. 2006) but these were beyond the scope of our study.

We conclude that although FPAs in our study had more fish and were generally well understood and valued compared with open areas, PPAs were not. PPAs along the Great Southern Reef did not generally achieve their broad social or ecological purposes yet they gave the illusion of protection and consumed scarce financial and spatial resources, acting as red herrings in marine conservation. Although some PPAs in other jurisdictions may reduce fishing pressure enough to provide ecological benefit, our results indicated there were large areas of coastline and multiple jurisdictions where this was not the case. We believe that if PPAs are to continue to be used to a large extent around the world, rigorous performance monitoring is required in order to ensure they are providing adequate conservation return on investment and are meeting the expectations of stakeholders. We recommend that further integrated research be conducted to examine the social and ecological effectiveness of PPAs in other jurisdictions, and managers and decision makers should now move to reverse PADDD and implement strategies to upgrade protected areas toward full protection in order for MPAs to meet their intended purpose and justify conservation investment.

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Supporting Information

Additional information is available online in the Supporting Information section at the end of the online article. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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