Marine zoning revisited: How decades of zoning the Great Barrier Reef has evolved as an effective spatial planning approach for marine ecosystem-based management

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SUPPLEMENT ARTICLE

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Marine zoning revisited: How decades of zoning the Great Barrier Reef has evolved as an effective spatial planning approach for marine ecosystem-based management

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Abstract

1. For more than 40 years, marine zoning has played a key role while evolving as part of the adaptive management of the Great Barrier Reef (GBR) Marine Park. The statutory zoning plan provides the primary integrating component that prohibits many threatening activities and manages the impacts of allowed human activities and competing uses by means of various zones, special management areas and other spatial management tools.
2. How zoning is applied, however, has changed considerably since the first zoning plan was finalized in 1981. Today, zoning is applied in combination with other layers of marine spatial planning; the effective combination of these management tools provides the integrated approach, considered one of the best for managing a large marine protected area.
3. The zoning plan provides the foundation for management of the GBR and is the fundamental component of the integrated marine spatial planning approach ensuring high levels of protection for significant areas of the GBR, while also allowing ecologically sustainable use.
4. The paper outlines the legal and managerial contexts of zoning, providing 38 lessons that may be useful for marine zoning and ecosystem-based management elsewhere. It outlines aspects of zoning that have worked well in the GBR Marine Park and what has changed in the light of experience and changing contexts, and seeks to clarify various misconceptions about zoning and marine spatial planning.
5. The integrated management approach in the GBR utilizes a variety of spatial planning tools, which complement the underlying zoning; some of these comprise statutory management layers (e.g. designated shipping areas, special management areas, plans of management, fishery management arrangements, Traditional Owner agreements, defence training areas); other layers are non-statutory (e.g. site plans).
6. This paper is written for planners, managers and decision-makers considering the use of zoning to achieve effective marine conservation, protection and ecologically sustainable use.

KEYWORDS

EBM, ecosystem approach, Great Barrier Reef, MPA, MSP, planning, spatial planning, zoning

1 | INTRODUCTION

1.1 | What is marine zoning and how has it been used in the Great Barrier Reef?

Zoning is a spatial planning tool, derived from concepts developed in land-use planning, to allocate rights and responsibilities for use and entry to areas. Zoning can separate competing uses or regulate uses to protect sensitive, ecologically valuable or recovering areas. Different zones may allow different uses, or different levels of use based on a determination of an area's suitability for those uses, with the added aim to minimize conflicts between incompatible uses (Agardy, 2010).

Over the last 40 years, marine zoning (sometimes called ocean zoning) has become a key component in managing marine areas. Zoning has become increasingly important as the number of large-scale marine protected areas (MPAs) has increased. The concept continues to be increasingly utilized, and many contemporary texts on managing marine areas refer to ocean or marine zoning. Numerous publications highlight the importance of zoning in marine management (e.g. Agardy, 2010; Crowder & Norse, 2008; Douvere, 2008; Edwards, 2008; Foley et al., 2010; Halpern, McLeod, Rosenberg, & Crowder, 2008; Jones, Lieberknecht, & Qiu, 2016; Katsanevakis et al., 2011; Mcwhinnie, Briers, & Fernandes, 2015; Norse, 2002; Portman, 2007; Yates, Schoeman, & Klein, 2015).

The Great Barrier Reef (GBR) Marine Park (GBRMP) is considered by many as one of the world's better working examples of marine zoning. Ruckelshaus, Klinger, Knowlton, and DeMaster (2008) concluded: 'The Great Barrier Reef ecosystem boasts a system-wide spatial management approach that is arguably the world's most sophisticated and extensively implemented example of marine zoning'. Agardy (2010), in a chapter about the GBR in her book *Ocean Zoning*, described the GBRMP as '… an iconic marine park that may well provide the best example of large-scale ocean zoning in existence today'. The integrated approach for managing the GBR has long been acknowledged with local, national and international accolades.

When the GBRMP Act was proclaimed in 1975, it was pioneering legislation as it provided for both 'conservation and reasonable use' of natural resources, introducing the concept of multiple-use spatial management through zoning as the key management tool for the GBRMP. This federal legislation arose because of broad public concerns about the need to manage the iconic environment of the GBR in the face of increasing and potential threats, including oil drilling and limestone mining, as well as new technologies (Supplementary Information Text S1 provides more information about the history of zoning in the GBR).

For many decades, the GBRMP was the world's largest MPA,[1] and marine zoning has always been the cornerstone of its integrated management approach. Today, the GBRMP covers an area about the same size as Germany, Malaysia or Japan, or about half the size of the US state of Texas. Within the boundaries of the GBRMP, zoning provides a key layer of marine spatial planning (MSP) with the objective of integrating conservation and a wide range of reasonable human uses and activities. Zoning is complemented by a comprehensive management regime that includes cross-jurisdictional management, and collectively this protects one of the world's most diverse marine ecosystems.

The current spectrum of zones in the GBRMP is shown in Table 1; the various zones determine what activities are allowed and where. The comprehensive multiple-use zoning system governs all human activities, providing high levels of protection for specific areas, whilst allowing a range of reasonable uses, including certain extractive activities, to continue in other zones. Activities allowed within the GBRMP include shipping, boating, diving, many types of tourism and recreation, various forms of commercial and recreational fishing, aquaculture, research, developmental works, including dredging and spoil disposal, traditional uses and defence training activities. Most of these, however, may only occur in specific areas or zones, and many require a permit containing detailed conditions determined through systematic evaluation and assessment.

Although most of the existing publications on ocean or marine zoning support the approach, very few are able to articulate the lessons learned after years of planning and implementing a zoning approach. Furthermore, only a few papers (e.g. Leenhardt, Cazalet, Salvat, Claudet, & Feral, 2013; Singleton & Roberts, 2014; Toonen et al., 2013) deal specifically with zoning a large-scale MPA, despite the increasing global adoption of this approach.

The two primary authors of this paper have, at different times, been directly involved in the practical development and application of zoning since the concept was first introduced in the GBR. Both have previously documented some of the zoning lessons in the GBRMP (e.g. Day, 2002, 2011, 2015; Day, Fernandes, Lewis, & Innes, 2004; Fernandes et al., 2005; Kelleher & Kenchington, 1990; Kenchington, 1992; Kenchington & Day, 2011; Lawrence, Kenchington, & Woodley, 2002).

This paper documents further lessons in the application of zoning to this large MPA. It outlines the fundamental role that zoning has

[1]The GBRMP Act declared the outer boundary of the GBR region in 1975, but management within the area did not commence until 1979 when the Capricornia Section of the Marine Park was declared and zoned. Over the next nine years, various sections of the GBRMP were progressively declared and zoned, with each section learning from its predecessors. The GBRMP remained the world's largest MPA (344,400 km^2) from 1988 until 2000 when a second large-scale MPA was declared. The North-western Hawaiian Islands Coral Reef Ecosystem Reserve was established in 2000; and in 2006, that reserve was expanded and recognized as the Papahānaumokuākea Marine National Monument (362,074 km^2) and expanded again in 2016 (1,508,870 km^2). Between 2009 and 2017, a further 14 large-scale MPAs were established, and together these large-scale MPAs now account for more than 11×10^6 km^2 of the world's oceans.

TABLE 1 Great Barrier Reef zones and their legal zone objectives in 2019

Zone name	Zone colour	Legal objective(s) for the zone
General Use Zone	Light blue	to provide for the conservation of areas of the Marine Park, while providing opportunities for reasonable use
Habitat Protection Zone	Darker blue	(a) to provide for the conservation of areas of the Marine Park through the protection and management of sensitive habitats, generally free from potentially damaging activities; and (b) subject to (a), to provide opportunities for reasonable use
Conservation Park Zone	Yellow	(a) to provide for the conservation of areas of the Marine Park; (b) subject to (a), to provide opportunities for reasonable use and enjoyment, including limited extractive use
Buffer Zone	Olive green	(a) to provide for the protection of the natural integrity and values of areas of the Marine Park, generally free from extractive activities; (b) subject to (a), to provide opportunities for: (i) certain activities, including the presentation of the values of the Marine Park, to be undertaken in relatively undisturbed areas; and (ii) trolling for pelagic species
Scientific Research Zone	Orange (or green with an orange outline/border)	(a) to provide for the protection of the natural integrity and values of areas of the Marine Park, generally free from extractive activities; and (b) subject to (a), to provide opportunities for scientific research to be undertaken in relatively undisturbed areas
Marine National Park Zone	Green	(a) to provide for the protection of the natural integrity and values of areas of the Marine Park, generally free from extractive activities; and (b) subject to (a), to provide opportunities for certain activities, including the presentation of the values of the marine park, to be undertaken in relatively undisturbed areas
Preservation Zone	Pink	to provide for the preservation of the natural integrity and values of areas of the Marine Park, generally undisturbed by human activities
Commonwealth Islands Zone	Cream	(a) to provide for the conservation of the natural integrity and values areas of the Marine Park above low water mark; and (b) to provide for use of the zone by the Commonwealth; and (c) subject to (a), to provide for facilities and uses consistent with the values of the area

played in the GBRMP, provides some of the history and legal context of zoning, highlights the lessons learned about zoning after over 40 years of 'adaptive management', outlines what aspects of zoning have worked well and what has necessarily changed, and clarifies various misunderstandings about zoning and MSP. This paper aims to compile all the lessons about GBR zoning, as well as suggestions and implications for marine zoning elsewhere, into a single publication.

1.2 | How does ocean or marine zoning differ from MSP?

The terms 'ocean zoning', 'marine zoning' and 'MSP' are sometimes considered as alternatives, exacerbated by the fact that 'zoning' and 'spatial planning' were both originally terrestrial planning concepts. In the two-dimensional terrestrial planning context, zoning is a technique of spatial planning for land use. Terrestrial area planning provides for the allocation of zones establishing primacy for within-boundary purposes such as urban development, agriculture, transport infrastructure or environmental protection.

In the three-dimensional context of marine space, zoning is similarly a technique for allocating or recognizing purposes of use or entry for specific marine areas. MSP often comprises multiple elements integrating spatial plans for different sectoral uses of the same marine area.

The interrelationship between zoning, MSP and ecosystem-based management as they occur in the GBRMP is explained in the following:

- Zoning can provide *a sound legal framework for spatial management*—In the marine environment, zoning can act in multiple layers (e.g. encompassing the overlying water column and the sea bed within an MPA), but zoning is *just one legal layer for management*.
- MSP may comprise *multiple layers of spatial planning* comprising different spatial plans or planning layers, but *each layer has its own legal framework*. Zoning may be one layer or one component of MSP; however, MSP is still confined only to the marine environment (i.e. the waters or the sea bed).
- A comprehensive ecosystem-based management approach recognizes that what happens in the adjoining coastal and oceanic areas usually has a major influence on the marine components within an MPA and on other (spatially managed) marine activities. Therefore, to achieve effective conservation of marine biodiversity, *three-dimensional or multilayered management and planning across both the terrestrial and the marine realms* (and that includes the airspace above and the sea bed below), both inside and outside an MPA, are all pertinent.

Within the GBRMP, when other management layers from other agencies or sectors are applied using their own specific legislation or legal frameworks, they are still subject to the overall zoning framework, and therefore all activities must be consistent with the underlying zone objectives.

2 | A BRIEF HISTORY OF ZONING IN THE GBR

The following is a brief summary of the history of zoning in the GBR (see Supplementary Information Text S1 for a more detailed history of zoning).

The GBRMP Act arose because of broad public concerns about the future of the iconic environment of the GBR in the face of increasing and potential human activities, new technologies and a response to unprecedented coral predation by crown of thorns starfish (Kenchington, 2018). The federal act established zoning as the framework for managing the GBR. This required engagement by the newly established GBRMP Authority (GBRMPA) with pre-existing industries, including tourism, recreation and various types of fisheries, in order to address the integration of conservation with these pre-existing sectoral contexts.

In 1979, the federal and Queensland (state) governments signed an administrative agreement (known as the Emerald Agreement). This agreement determined that whereas overall management of the GBR would be undertaken within the framework of the federal legislation (the GBRMP Act), most existing sectoral management arrangements (e.g. fisheries management, tourism, recreational boating) would continue to be managed by Queensland agencies.

The first section of the GBRMP that was zoned was the Capricorn and Bunker Group of islands and reefs. The Capricornia Section was chosen because the area was relatively small,[2] accessible, separated from the outer GBR and there was reasonable scientific and usage data. The first zoning plan came into effect in 1981 with a spectrum of zone types, ranging from a General Use Zone (the least restrictive zone, allowing most reasonable uses), through to a Preservation Zone (very small 'no-go' areas, set aside as scientific reference areas). Early zoning plans allowed access to all zones in special circumstances (e.g. for saving human life, or for securing a vessel endangered by weather or other hazards).

Over the years, zoning was progressively applied to different sections of the GBRMP, and many aspects of zoning have been refined and other management approaches introduced in the light of experience by the GBRMPA to supplement the zoning. Sequential declaration and zoning of the majority of the GBR was not completed until 1988.

Many aspects of zoning have been refined over the decades (Day, 2002, 2016; Kenchington & Day, 2011). In summary:

- The initial focus for zoning in the 1980s was primarily on coral reefs, with less consideration of the associated ecosystems in inter-reefal areas. There was limited baseline information on seabed communities, and the concept of excluding fishing from very large areas with existing or potential fishing value was highly contentious. The first such zoning that prohibited extractive activities, including fishing, within a large single area, was a remote and 'pristine' cross-shelf transect of National Park Zone in the Far Northern Section in 1985. Until 2003 this single zone comprised 72% of the total extent of no-take zoning in the GBRMP.
- Over the decades, various changes have occurred with respect to zoning, including:
  - zone names changed;
  - zone objectives were clarified and expanded (see Supplementary Information Table S2);
  - the description and depiction of zones changed; and
  - some of the understandings as to what zoning can and cannot achieve also changed (further information is available in Section Part 4 and in Supplementary Information S3.1–S3.3)
- Subsequent zoning plans also made provision for other spatial layers of management within the zoning plan (e.g. shipping areas, special management areas).
- By the late 1990s, the revisions to the reporting requirements to the World Heritage Committee required a finer scale understanding of components of the Outstanding Universal Value of the GBR. The GBRMPA commissioned a study (Lucas, Webb, Valentine, & Marsh, 1997) that found that the existing levels of zoning protection focused on keystone species and habitats and did not adequately protect the full range of biodiversity known to exist within the GBR. Consequently, the existing levels of protection were inadequate to ensure that the entire GBR remained healthy, productive and resilient into the future.
- Between 1999 and 2003, a complex planning and consultative programme was undertaken to develop a new zoning plan for the entire marine park (Day et al., 2004; Fernandes et al., 2005; GBRMPA, 2005). The primary aim of the programme was to better protect the full range of biodiversity in the GBR, by increasing the extent of 'no-take' areas, ensuring they included 'representative' examples of all the different habitat types (hence the name, the Representative Areas Program or RAP).

From mid-2004, and still current in 2019, there are seven marine zones and one island zone in the GBRMP, as shown in Table 1.

The words 'conservation' and 'protection' are both used in the legal objectives of specific zones (Table 1), and both are defined in the Zoning Plan:

- 'Conservation' is defined as 'the protection and maintenance of nature while allowing for its ecologically sustainable use'. Conservation is therefore used for the General Use, Habitat Protection,

[2]The Capricornia Section covered an area of ~12,000 km^2, contained 21 reefs and three vegetated cays and was already subject to considerable tourist pressure (Bowen & Bowen, 2011).

Conservation Park and Commonwealth Islands zones, where the primacy is about allowing for ecologically sustainable use.

- 'Protection' is defined as 'the taking care of the place by managing impacts to ensure that its natural significance is retained'. Protection is used for the Buffer, Scientific Research and Marine National Park zones; and when used in conjunction with the words 'the natural integrity and values', the primacy is about retaining the natural significance of the values.

The fact that the words 'protection (or preservation) of the natural integrity and values' appear in the objective for four of the eight zone types is significant, especially as the objective of a zone is one of the mandatory requirements to consider when assessing whether a permit should be granted to use or enter a zone (see also Part 3).

Both words also appear in the primary objective of the GBRMP Act ('… to provide for the long-term protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef Region' (s. 2A (1) of the Act).

Today (i.e. 2019), the zoning for the entire GBR is as shown in Figure 1, with the activity guide at Figure 2 indicating what is allowed in each zone. The extent of the different zones and the extent of the different zones and their percentage of the GBRMP are shown in Table 2.

3 | THE CURRENT APPROACH TO ZONING IN THE GBR

Key aspects of the current zoning approach in the GBR are outlined below. More details expanding each of these aspects including how zoning has developed, are provided in Supplementary Information Text S2.

- **A strong legislative basis for zoning.** The GBRMP Act outlines the systematic process required to develop a zoning plan, including mandatory requirements for seeking and considering public representations during specific phases of planning. The statutory zoning plan is also considered to be subordinate legislation to the Act.
- **A clearly defined spectrum of zones in the GBRMP.** These range from the least restrictive General Use Zone to the most restrictive Preservation Zone. Four of the GBR zone types (Marine National Park Zone, Scientific Research Zone, Preservation Zone and Commonwealth Islands Zone) are highly protected 'no-take' zones. Probably the best-known zone today is the Marine National Park Zone (locally known as a 'green zone'), which allows public access but prohibits any extractive activities, such as fishing or collecting.
- **Explicit zone objectives.** Some zone objectives have multiple components (e.g. to provide for both conservation and reasonable use, as shown for most zones in Table 1). In such cases, there needs to be a clear hierarchy within zone objectives, so the second component of the objective is always subject to the first (i.e. reasonable use can only occur if it is compatible with conservation).
- **A clear definition of which activities are appropriate within each zone.** The Zoning Plan provides two specific lists of 'use or entry' provisions for each zone type in the GBRMP:
  1. the first list specifies activities allowed to occur 'as of right' in that zone (i.e. they are allowed, and they do not require a permit);
  2. the second list specifies activities that may occur in that zone, but only after the activity has been assessed for a permit and, if the application meets all the necessary requirements, a permit has been granted.
- **Publicly available zoning maps that depict the location of all zones.** Some zone coordinates are shown on the zoning maps (e.g. those considered important for most users, such as the no-fishing (green) zones and no-access (pink) zones). However, not every zone coordinate is shown on the zoning maps.
- **Complementary zoning across adjoining jurisdictions.** In November 2004, the State of Queensland 'mirrored' the Commonwealth zoning in most of the adjoining State waters, so there is now complementary (i.e. matching) zoning for virtually all the State and Commonwealth waters within the entire GBR World Heritage Area[3] from high water mark, across all tidal lands and tidal waters, and all the way out to the edge of the federal Marine Park, which at its widest is 250 km offshore. This complementary approach aids the efficacy of the actual zoning for ecosystem management and helps enormously to assist public understanding and compliance with zoning.

The map shown in Figure 4 illustrates some of these points, with all seven marine zones occurring in the area shown.

4 | KEY ASPECTS OF GBR ZONING THAT HAVE CHANGED OVER THE DECADES

The history of the GBR zoning is described in more detail in Supplementary Information Text S1 and Table S3; however, four key changes in the approach to zoning in the GBR are summarized here:

- **The wording of the legislative objectives for each zone has been clarified.** The importance of the zone objectives as the primary basis for determining the appropriateness of any activity in a particular zone is fundamental; each zone must have clear objectives.
- **How zone boundaries are defined and described has changed.** Originally, zone boundaries were described as a specified distance from a geographical feature, like the reef edge (see Figure 3a). This was the best possible approach given the technology available at the time. The introduction of satellite navigation and the Global Positioning System (GPS) enabled coordinate-based zone

[3]The GBR World Heritage Area (348,00 km^2) is slightly larger than the GBRMP (344,400 km^2) because it includes all 1,050 islands and all their surrounding waters within the outer boundaries of the World Heritage Area, all waters seaward of low water mark on the mainland coast (including internal waters of Queensland) and all port waters.

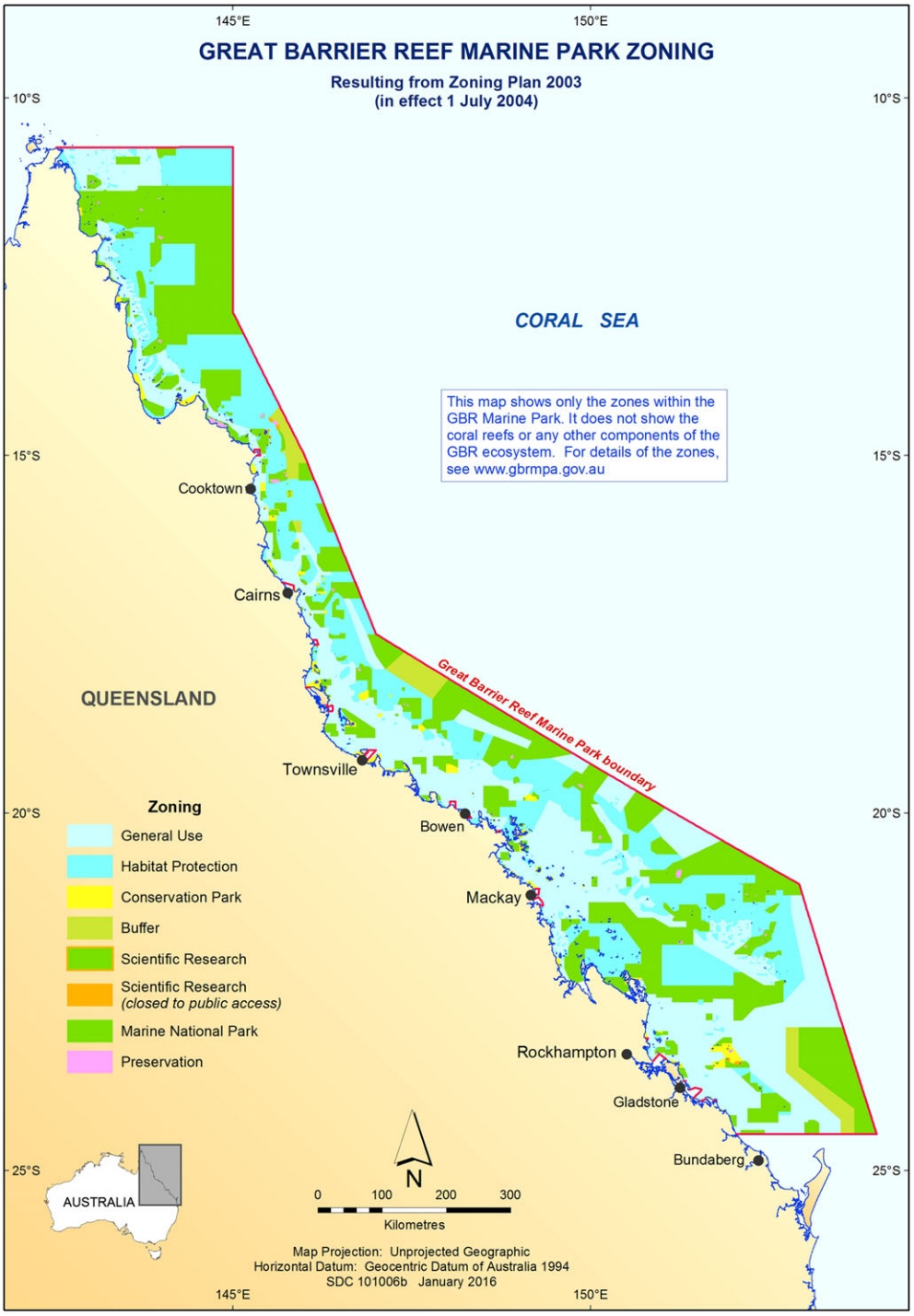

FIGURE 1 Current zoning for the Great Barrier Reef Marine Park (resulting from the 2003 zoning plan—in effect July 1, 2004; note the Commonwealth Islands Zone does not appear at this scale). Source: © Commonwealth of Australia

boundaries to be introduced in the 2003 Zoning Plan with zones described by their longitude/latitude coordinates specified in degrees and decimal minutes (as shown in Figure 3b). Over the last decade, this technology has become much more affordable and widely available. Straight lines using coordinate-based zone boundaries are far easier to locate and enforce in offshore areas, especially when they fully encompass ecological features (i.e. well outside the edge of entire reefs/islands). However, recognizing that not every user in the GBR has a GPS device, inshore zone boundaries are, wherever possible, aligned with recognizable coastal features or identifiable landmarks or boundary markers (e.g. 'The zone extends north from the easternmost extent of the headland at xxx').

- **Improved satellite mapping over the decades.** This has been an important contribution to planning and compliance by amending the mapped areal extent of many reefs (compare the reef outlines shown in Figures 3a and 3b), enabling the precise locations of reefs.

TABLE 2 Extent of zones in the Great Barrier Reef (GBR) Marine Park (July 1, 2004–present (2019))

Zone type	Zone area (km^2)[a]	Fraction of GBR Marine Park (%)	Closest equivalent International Union for Conservation of Nature category
General Use Zone	116,530	33.8	VI
Habitat Protection Zone	97,250	28.2	VI
Conservation Park Zone	5,160	1.5	IV
Buffer Zone	9,880	2.9	IV
Scientific Research Zone	155	<1	Ia
Marine National Park Zone	114,530	33.3	II
Preservation Zone	710	<1	Ia
Commonwealth Islands Zone[b]	185	<1	II
Total	344,400	100	VI (Ia, II, IV and VI)

[a]Areas from Day & Dobbs, 2013.

[b]Commonwealth islands only.

- **Zone names have changed.** The original zone names were derived from an approach used in terrestrial zoning, but were changed over successive zoning plans, with the aim to indicate the primary purpose and reflect the objectives of the zone. As far as possible, the zone name should indicate the overall objective of the zone rather than a single activity that may be allowed or not allowed in the zone.

These changes were not due to zoning 'mistakes' that needed to be quickly addressed because the initial zoning plans were inadequate, but rather adaptions over many years, because so much has changed within, and around, the GBR. Changes include increasing numbers of users, new and emerging threats, better scientific information, improved technology for demarcation and surveillance, and increasing demands of stakeholders and rights holders in participatory planning.

Other significant changes that have implications for zoning reflect technological advances; for example, the availability of GPS devices is a 'double-edged sword' that may provide management benefits but, at the same time, may exacerbate ecological threats by focusing use in particular areas (e.g. enabling easy location of fish spawning areas). The availability, size, ease of use and, most importantly, the cost of GPS devices and mobile phones has changed dramatically over the last decade, meaning that most MPA users are now able to accurately determine their location (see Supplementary Information Text S5 for more details).

GBRMP Zoning
(see relevant *Zoning Plans* and *Regulations* for details)

	General Use Zone	Habitat Protection Zone	Conservation Park Zone	Buffer Zone	Scientific Research Zone	Marine National Park Zone	Preservation Zone
Aquaculture	Permit	Permit	Permit*	✗	✗	✗	✗
Bait netting	✓	✓	✓*	✗	✗	✗	✗
Boating, diving, photography	✓	✓	✓	✓	✓*	✓	✗
Crabbing (trapping)	✓	✓	✓*	✗	✗	✗	✗
Harvest fishing for aquarium fish, coral and beachworm	Permit	Permit	Permit*	✗	✗	✗	✗
Harvest fishing for sea cucumber, trochus, tropical rock lobster	Permit	Permit	✗	✗	✗	✗	✗
Limited collecting	✓*	✓*	✓*	✗	✗	✗	✗
Limited spearfishing (snorkel only)	✓	✓	✓*	✗	✗	✗	✗
Line fishing	✓*	✓*	✓*	✗	✗	✗	✗
Netting (other than bait netting)	✓	✓	✗	✗	✗	✗	✗
Research (other than limited impact research)	Permit	Permit	Permit	Permit	Permit	Permit	Permit
Shipping (other than in a designated shipping area)	✓	Permit	Permit	Permit	Permit	Permit	✗
Tourism programme	Permit	Permit	Permit	Permit	Permit	Permit	✗
Traditional use of marine resources	✓*	✓*	✓*	✓*	✓*	✓*	✗
Trawling	✓	✗	✗	✗	✗	✗	✗
Trolling	✓*	✓*	✓*	✓*	✗	✗	✗

PLEASE NOTE: This guide provides an introduction to Zoning in the Great Barrier Reef Marine Park. Relevant Great Barrier Reef Marine Park Zoning Plans should be consulted for confirmation of use or entry requirements.

* Additional restrictions / conditions apply.

ACCESS TO ALL ZONES IS PERMITTED IN AN EMERGENCY.

FIGURE 2 Great Barrier Reef Marine Park (GBRMP) activity guide/zoning matrix. This activity guide indicates the allowable activities in each of the seven marine zones in the GBRMP. A tick indicates the activity is allowed 'as of right', whereas a cross clearly shows that certain activities are prohibited in certain zones. 'Permit' means the activity can only occur once a permit has been assessed and, if appropriate, then granted with conditions. © Commonwealth of Australia.

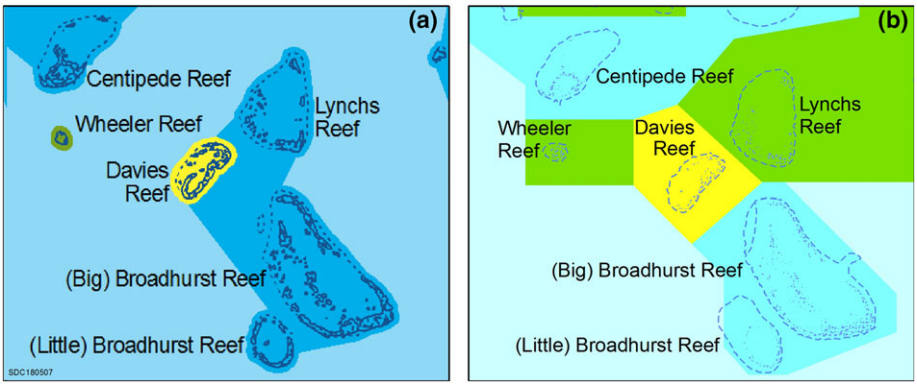

FIGURE 3 (a) The initial zoning for a group of reefs north-east of Townsville in the initial Central Section Zoning Plan. This enlargement shows the extent of the actual reefs indicated by the blue dotted lines. At this time (2001), zones were usually described as a specified distance from the reef edge (consequently, the 'yellow' zone around Davies Reef was described as '500 metres from the reef edge'), and many zone shapes corresponded to the shape of the reef. (b) Same area as in (a) showing the coordinate-based zoning that was introduced in the 2003 Zoning Plan. Key points to compare with (a) are that (i) most zone boundaries are straight lines between two identifiable GPS points, and (ii) the coordinate-based zones (generally) extend well outside the reef edges indicated by the blue dotted lines, encompassing some of the surrounding non-reef areas.

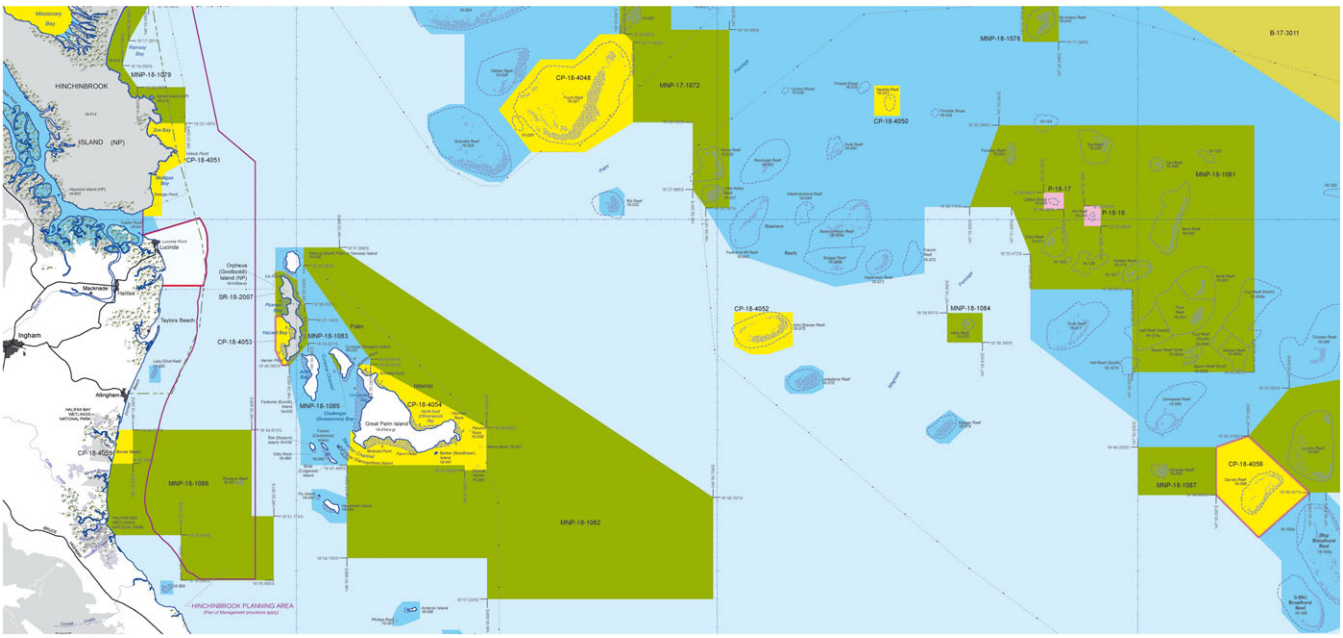

FIGURE 4 Part of the zoning map depicting the 2003 Zoning Plan for the area of the Great Barrier Reef Marine Park just north of the city of Townsville.

• All seven marine zones occur in the area shown, although, at this scale, the Scientific Research Zone (SR-18-2007) on the northern end of Orpheus Island (centre left) is not obvious (orange border around a Green zone) and the Buffer Zone is barely recognizable in the top right-hand corner. Clearly apparent, however, are the straight-line boundaries of most zones, most of which encompass whole ecological units—as are the actual zone coordinates for areas of key importance (e.g. the no-fishing (green zones) and no-access (pink zones)).

• Various islands are also obvious (e.g. Hinchinbrook Island in the top left-hand corner is a large national park; Great Palm Island in the middle-left supports a significant Indigenous community); around both islands, the federal Marine Park commences at low water, but the complementary State Marine Park covers the tidal lands and tidal waters between high and low water. The long, narrow channel between Hinchinbrook Island and the mainland is considered to be 'internal waters' (i.e. State-controlled 'internal waters' on the landward side of a defined baseline but still covered by the State zoning).

• The Port of Lucinda appears as an irregular-shaped white-coloured exclusion with a red boundary adjoining the coast (to the south of Hinchinbrook Island). The port exclusion area is under Queensland jurisdiction but is not part of either the federal or state marine parks; these port waters, however, are part of the Great Barrier Reef World Heritage Area.

Source: © Commonwealth of Australia

• A zoomable e-version of this map is available at http://elibrary.gbrmpa.gov.au/jspui/bitstream/11017/602/4/Map7-EditionV-Townsville.pdf

5 | WHAT ZONING CAN AND CANNOT DO IN AN MPA

5.1 | Zoning is not always the most effective marine management tool

Zoning is a well-recognized form of marine planning and management that can provide a spatial management framework separating conflicting uses and underpinning management. However, it is not necessarily the most effective management tool for all activities or impacts affecting that area. Table 3 lists some impacts that are not effectively addressed by zoning alone; however, the majority of these impacts are not able to be addressed by any other marine management tool in isolation either, hence the subsequent discussion and Tables 4 and 5.

Most of the impacts in Table 4 are managed using other management 'tools' developed mainly by other sectoral agencies using their own specific legislation. However, in the GBRMP, when management tools from other agencies or sectors are applied, they are still subject to the overall zoning framework and therefore must be consistent with the underlying zone objectives. Indeed, it is apparent that strong and responsible legislation in other jurisdictions (e.g. fisheries management) is critical in ensuring that the management objectives of the GBRMP are achieved. For example, the recently released Queensland Sustainable Fisheries Strategy 2017–2027 (Fisheries Queensland, 2017) refers to the importance of sustainable fisheries contributing to a healthy GBR.

5.2 | Other spatial and temporal tools in the GBR Zoning Plan that complement the underlying zoning

Various multidimensional management tools (spatial, non-spatial and temporal) are applied on top of the underlying zoning in the GBRMP with the specific aim to address particular activities in the GBRMP. Some of these spatial and temporal management tools form part of the statutory GBR Zoning Plan (Table 4), whereas other management layers exist in other statutory documents (Table 5).

5.3 | Further spatial tools that complement zoning

Table 5 lists examples of some other spatial and temporal management tools that are not part of the GBR Zoning Plan, but which specifically address significant activities that occur within the GBRMP. Further information is also provided in Supplementary Information Table S4.

TABLE 3 What zoning can, and cannot do, to address aspects impacting marine conservation

Aspects impacting on marine conservation	What zoning can, or cannot, do to address these aspects
Water quality, particularly that arising outside the marine protected area (MPA)	Marine zoning (as the name clearly implies) only applies within marine waters, whereas many water quality issues impacting MPAs arise on the land; other types of zoning may be applicable on land, but that is generally managed under another agency or jurisdiction.
Climate change	Ocean or marine zoning can help build and maintain resilience but does not address the drivers such as rising sea temperatures, increased storm intensity or ocean acidification.
Unsustainable fishing impacts	Zoning can provide effective spatial controls on where various types of fishing may or may not occur (Kenchington, Kaiser, & Boerder, 2018). It may also describe which fishing gear may be used in which zone. Special management areas overlying zones where fishing occurs may further mitigate risks posed by some fishing activities. However, zoning should be complemented by use of specific fisheries management tools (spatial and/or temporal) to be effective.
Coastal developments, especially ports	Zoning will not apply in ports if they are located outside the jurisdictional control of an MPA. Zoning will only regulate activities like dredging and spoil dumping if these activities are specifically mentioned in the zoning plan.
Shipping and pollution incidents	A zoning plan over an MPA may help by delineating shipping lanes but is unlikely to directly address shipping threats, including ship groundings and marine pollution. These activities are often the responsibility of other government agencies rather than the MPA managers.
Tourism impacts	Different forms of tourism are generally allowed to operate under permit in most zones within an MPA; however, the zones themselves rarely provide for a spectrum of tourism settings or use levels. In the Great Barrier Reef, the existing spectrum of zones is focused on extractive activities and was shown to be ineffective to provide a useful spectrum of tourism settings (hence the requirement for 'Plans of management' as described in Table 6).
Increasing population growth and consequent increasing use of MPAs	Marine zoning is not able to address key issues relating to population growth unless the zones can be used to curtail use or reduce some of the consequential impacts in recreation or tourism growth.

TABLE 4 Other spatial and temporal management tools that differ from the zones but are within the statutory Great Barrier Reef (GBR) Zoning Plan

Management tool	Description of tool	Scope
Special Management Areas (SMAs)	The statutory Zoning Plan has provisions for additional restrictions on access to, or use of, specified areas of the GBR Marine Park (GBRMP) for well-defined conservation or management purposes. The current zoning plan details six types of SMAs, allowing additional restrictions for reasons such as: • conservation of a particular species (e.g. key locations for turtle or dugong; bird nesting sites or fish spawning aggregation sites); • public safety; • special public appreciation; • maritime cultural heritage protection; • response to an emergency (e.g. a ship grounding, oil spill).	Spatial and temporal
Remote Natural Area	This statutory layer sits on top of the underlying zoning and ensures the specified area remains in a state largely unaltered by works or facilities, and without noisy activities such as motorized water sports (see Part 3 within the statutory Zoning Plan)	Spatial
Designated shipping areas	Designated shipping areas (shown in Figure 5b) provide for the safe navigation of ships but comprise a separate layer that overlays the underlying zoning (see Part 4 within the statutory Zoning Plan)	Spatial
Fisheries experimental areas	These areas were designed to allow specific areas of the GBR to be used for scientific research into the effects of fishing on the living natural resources and ecosystems of the GBRMP (known as the 'Effects of line fishing' experiment). These experiments have now concluded.	Spatial and temporal
Additional purposes for use and entry	Part 5 within the statutory Zoning Plan has special provisions for certain activities to occur, including: • without permission or prior notification (e.g. to save human life; deal with a threat to the marine environment such as pollution or a threat to human safety); or • after notification, but not requiring a permit (e.g. to remove or salvage a wreck; construct or operate a navigational aid; undertake defence activities; undertake government surveys or essential services authorized under law); or • with a permit, the taking of an animal or plant of a protected species.	Temporal (as required)
Permits	Permits are often tied to a specific zone or zones or specified areas within zones. They provide a detailed level of management regulated by specific conditions that would not otherwise be possible by zoning alone.	Spatial and temporal

TABLE 5 Other spatial and temporal management tools not within the GBR Zoning Plan but which address particular activities occurring within the GBR Marine Park

Examples of other management tools	Description of tool	Scope
'Plans of management'	Statutory plans for high-use areas, such as popular tourist destinations, or high value areas (e.g. offshore Cairns; the Whitsunday Islands; or the Hinchinbrook area, as shown in Figure 5d).	Spatial
Site plans	Localized plans that prescribe management arrangements for use of a particular site concentrating on specific use issues and cumulative impacts at that site (these plans are considered to be non-statutory policy).	Spatial
Other fishery management arrangements	These include management arrangements, such as gear restrictions, in-possession or bag limits, size limits, limited entry, total allowable catch limits; spatial restrictions like dugong protection areas; or temporal management arrangements, such as seasonal closures at key fish spawning times.	Spatial and/or temporal
Plans addressing Indigenous interests	Formal (i.e. statutory) agreements with Traditional Owners, such as Traditional Use of Marine Resources Agreements or Indigenous Land Use Agreements applying to specific areas as recognized by the Traditional Owners (more information at Supplementary Information Text S4.2).	Spatial and temporal

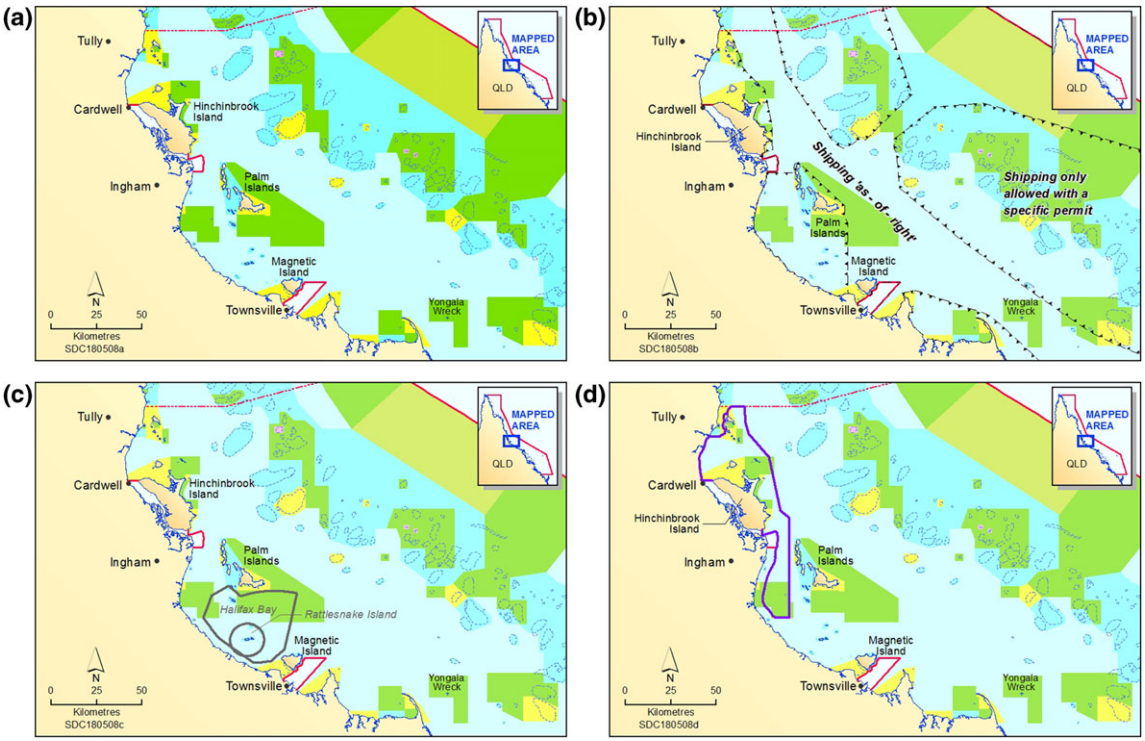

FIGURE 5 Small subsets of the Great Barrier Reef (GBR) Marine Park showing various spatial management layers on top of the underlying zoning. (a) Part of the 2003 zoning plan showing the range of zones in a small area off Townsville in the central part of the GBR. This same area is then depicted in the maps (b)–(d) with other spatial management arrangements shown on top of the underlying zoning. (b) Shipping is one of many examples of marine activities that are not limited to a single zone within a multiple-use zoning scheme. Shipping lanes are part of the statutory zoning plan; but, as shown, shipping lanes go across many of the underlying zones. For most users, however, shipping lanes are not obvious on the publicly available zoning maps. All ships need to be aware where the statutory shipping lanes occur, with large penalties possible if they transgress. (c) Whereas some Defence Training areas in the GBR provide permanent closures to the public, others, like this one, are not permanent. For example, when this area is being used for defence training purposes, it is closed to all users by Public Notice under a separate statutory basis. However, for the majority of the year, the area is open with very few restrictions other than the underlying zoning (i.e. this training area is both a spatial and a temporal arrangement). (d) A small subset of the mapped area shown by the purple outline is highly used with potential conflicts between tourism, recreation and conservation aspects. Another statutory plan (a 'Plan of Management') has been specifically developed to address these issues. In a similar plan (the Whitsunday Plan of Management), an overlay of different tourism settings is applied irrespective of the underlying zoning.

Examples of non-spatial management tools include bag limits and size limits for fishing, and a wide range of permits; temporal management tools include seasonal closures at key fish spawning times or temporary closures for short-term activities like military training exercises.

Some of the aforementioned spatial and temporal layers overlying the GBR zoning are depicted in Figure 5b–d, showing the same area of the GBRMP with differing management layers. So, rather than a single MSP layer or a single GBR management plan, a comprehensive multilayered management system exists, covering the sea surface, the adjacent airspace, the water column and a specified distance into the sea bed and comprising a wide range of federal and state agency management arrangements and plans (e.g. fisheries management arrangements, port plans, shipping plan).

Virtually all the management tools in Tables 4 and 5 have their own statutory basis and specific objectives. However, when these are addressed within the GBRMP, they must be consistent with the relevant zone objectives. The GBRMP Act provides precedence over inconsistent provisions of nearly all other federal laws[4]; and under the Australian Constitution, federal laws have precedence over inconsistent Queensland State laws (Kenchington & Day, 2011).

This full suite of management tools and management approaches has been adaptively improved over the past three decades. Collectively, they comprise a comprehensive management framework, most of the components of which are integrated and coordinated across agencies and across jurisdictions. However, not every aspect of spatial management is shown in the publicly available zoning maps.

Marine park zoning can only apply within areas that are declared marine parks (federal or state); the zoning, therefore, does not apply to adjoining port areas or many adjoining estuaries and passages, even

[4]Shipping is one exception; designated shipping areas reflect lanes or corridors consistent with provisions of the navigation/shipping legislation, which under the Australian Constitution has precedence and enables management of foreign flagged vessels and legal follow-up beyond Australian waters (Kenchington, 1990)

TABLE 6 Generic lessons about marine or ocean zoning (primarily based on lessons from zoning in the Great Barrier Reef (GBR))

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
1. **Zoning should not be considered the only tool for marine management.** Zoning should be used in conjunction with other management tools (spatial and temporal).	Marine zoning can separate and impose conditions on competing and incompatible uses or regulate uses to protect sensitive, ecologically valuable or recovering areas. However, to be effective, zoning needs to be legally robust and not easily circumvented. This can result in a lack of flexibility, whereas a more flexible approach is conducive for adaptive management. The answer, therefore, is to not rely on zoning alone but instead to use zoning as the underlying framework in combination with other consistent spatial and temporal management tools. In the GBR, a range of multidimensional management tools (spatial, non-spatial and temporal) are applied, some of which are part of the statutory GBR Zoning Plan (see Table 4), whereas others are in additional statutory documents (see Table 5).	XX	XX	XX
2. **Legal framework.** A sound legal framework to back up any zoning, while not essential, will provide many benefits and enable more effective zoning.	Various sections in the GBRMP Act that provide a sound legal framework for planning and implementing GBR zoning are outlined in Supplementary Information Table S5. Many of the other management layers in the GBR are implemented by regulations and are therefore more easily modified. This approach provides 'the best of both worlds' (i.e. a strong legislative foundation for the underlying zoning, but the additional management layers are more flexible, and able to be more readily amended for adaptive management). Complementary zoning, each with its own but complementary legislative basis, means effectively the same zoning scheme applies across both jurisdictions (state and federal) within the GBR.	X	XX	XX
3. **Scientific understanding.** A comprehensive scientific understanding of an area to be zoned is not an essential prerequisite before developing a zoning plan.	Waiting for a complete scientific understanding before commencing a zoning programme is not only unnecessary but can potentially lead to bigger problems; in other words, start using the best available knowledge (see Lesson 16), but be prepared to adapt if new information becomes available.	XX	XX	X
4. Some form of **bioregionalization**, however, should be a prerequisite prior to developing a zoning plan.	Prior to developing a zoning plan, utilize basic ecological information (e.g. bathymetry) and apply rudimentary mapping principles (e.g. consider both latitudinal and longitudinal differences) to develop a basic regionalization representing the broad-scale patterns of biodiversity across the marine protected area (MPA), examples of which should all be afforded some protection. In the light of today's knowledge, the bioregionalization done prior to the GBR rezoning (in 1999–2000) looks dated. However, protecting representative examples of the 70 mapped bioregions has produced a GBR zoning network that has subsequently been shown to increase protection for the full range of biodiversity in the GBR, including features and species not known at the time of zoning but subsequently discovered (Bridge et al., 2011).	XX	XX	-
5. **Representative approach.** Zoning should aim to protect one or more representative examples of all known habitats within your MPA.	Having developed a broad-scale regionalization, then the application of basic planning principles (e.g. Fernandes et al., 2005) can help to develop a systematic and representative draft network that can then be released for public comment. The benefits of adopting a	X	XX	X

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
	representative approach are discussed in Lesson 5 in Supplementary Information Table S5.			
6. Although the International Union for Conservation of Nature advocates protecting **at least 30% of marine waters in highly protected area**, this does not mean every MPA needs to aim to protect this percentage from the time of initial designation.	The rationale behind a percentage recommendation for marine protection continues to be widely debated (e.g. Agardy, Claudet, & Day, 2016; De Santo, 2013). In the GBR, the best scientific advice was that, if the systematic planning principles were implemented in full, the expectation was that around 25–30% of the GBRMP would be in highly protected areas (GBRMPA, 2002). Instead of aspiring for an overall total percentage, the initial aims for any MPA should be to implement (a) a politically acceptable level of protection informed by the best science for every identified bioregion (i.e. a representative approach), and (b) adaptively manage this percentage over time as more information becomes available.	X	XX	X
7. **Spectrum of zones.** The aim in any zoning plan should be to ensure a spectrum of zone types.	The emphasis should be on providing a spectrum of zones with differing objectives and identifying activities consistent with those objectives. Currently in the GBR, there are seven marine zone types and one island zone; experience would suggest that any new zoning programme should not contemplate too many zone types—rather, to use other spatial tools to ensure flexibility in management (see Lesson 1). Supplementary Information Table S1 lists 13 zoning programmes that have drawn upon the GBR zoning approach; with four or five zones being the mode for the number of zones across these 13 zoning plans.	XX	XX	X
8. **Role of political engagement.** Zoning cannot occur in a 'political vacuum'; zoning is primarily a political process that needs to consider the interests of all stakeholders and be in keeping with the political aspirations of the government(s).	It is important to engage key community and political players from the start of any planning process rather than waiting until nearer the completion of the process. Although some decision-makers would prefer all planning decisions to be consensus based or to achieve a 'win–win' for those concerned, neither of these aspirations is a realistic goal when dealing with issues of the magnitude and multi-sectoral complexity of most MPA planning processes. It is essential, therefore, to obtain political endorsement early in the planning process. Be mindful that other stakeholders (e.g. fishers) will also be lobbying politicians (who are likely to have empathy with them), so MPA planners need to be able to show how they intend to engage with fishers (and all other stakeholders and rights holders) to be able to appropriately consider their concerns. Day (2017a) describes how a 'Leaders guide' was prepared to help politicians and other key players understand the GBR rezoning from its commencement.	XX	XX	XX
9. Prerequisites for effective zoning include **high-levels of political buy-in** enhanced by ongoing public participation.	The high levels of political buy-in, building upon the comprehensive public participation, were among the fundamental reasons behind the success of the 2003 GBR zoning (e.g. Day, 2017a; Fernandes et al., 2005).	XX	XX	XX
10. **Public engagement.** All zoning processes should include genuine and effective public engagement; this requirement will generally preclude a relatively quick or inexpensive zoning process.	The successful development, political adoption and practical implementation of any new zoning plan will be largely determined by the extent to which local communities understand the need, purpose and	XX	XX	XX

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
	process of the zoning (or rezoning), and accept the plan strives to reflect all aspirations and interests. Effective and ongoing public engagement are therefore key fundamental aspects of developing and implementing any successful zoning programme. Successful engagement is also dependent on the willingness of community members and other stakeholders to engage on matters that are important to them, but also on the commitment of managers to also get it right. Day (2017a) provides 25 key lessons on ways to ensure more effective public engagement.			
11. **Adjacent areas.** Zoning needs to consider, and wherever possible complement, adjacent coastal and marine areas. This includes the need to consider other key marine-related policies.	Zoning without regard for the adjacent marine and coastal areas is 'likely a folly' (Agardy, 2010). Table 4 outlines many issues facing MPAs that cannot be effectively addressed by managing the marine realm alone and hence are not well managed by marine zoning; e.g. water quality (most water quality issues arise on land); coastal developments like ports (most are outside the jurisdictional control of an MPA); and climate change (management including zoning may help build resilience, but climate change is a global issue).	XX	XX	X
12. **Ecological connectivity** is an important concept when determining zoning.	Given the high levels of connectivity within marine systems, all available knowledge about aspects of connectivity should be considered when developing zones (McCook et al., 2009). For example, an effective 'source' reef for fished species may be appropriately zoned as a 'no-take' area given it is likely to replenish other reefs; conversely, an identified 'sink' reef may be appropriately zoned to allow fishing if it appears that this reef is replenished from adjacent source areas.	X	XX	XX
13. Wherever possible, zoning decisions should **consider all the values** (ecological, social, cultural and economic) within, and surrounding, an MPA.	Zoning can provide a key foundation for MPA management, but more effective ecosystem-based management will be achieved if consideration is also given to the wider context, both inside and outside an MPA, and within both the terrestrial and marine realms.	X	XX	XX
14. **Complementary zoning across adjoining jurisdictions.** Such zoning can provide many advantages, by enhancing public understanding as to what is allowed, or not allowed, across broad areas of the marine environment.	Complementary legislation refers to laws that complement or supplement each other, applying matching or 'mirrored' provisions to enhance public understanding or enhance the mutual strengths of the laws. Where there are adjoining jurisdictions (e.g. state, provincial and/or federal), the benefits of a complementary approach are numerous (e.g. increased public understanding; improved management of species that cross over jurisdictional (i.e. artificial) boundaries; enhanced compliance). Complementary management is also essential where governments cannot agree where a boundary occurs between their respective jurisdictions. If the same rules and regulations effectively apply either side, there is no need for the boundary between adjoining jurisdictions to be defined or mapped. Conversely, management is far more complicated if the rules are different in each jurisdiction and/or the boundary is ill-defined.	*X	*XX	*XX
15. **Zone by objective, not activity.** Zones should not be based around individual activities; rather, the key determinant should be activities that are compatible with the zone objectives.	In some parts of the world, zoning is based solely around allowing, or prohibiting, specific activities in specific areas. However, in many MPAs there are numerous existing or potential marine activities that need to be	XX	XX	X

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
	managed. Many of these activities are not antagonistic; if so, those can occur within the same zone. If zoning is used to manage existing activities (and ocean/marine zoning is a key tool to do so), then it is preferable that zoning be by objective rather than by each individual activity. The difference between zoning by objective instead of zoning by activity is best explained by an example; a 'no-trawling' zone may indicate clearly one activity is prohibited (i.e. trawling is banned), but it is not clear as to what other activities may be allowed or not allowed. To assist public understanding, the allowable activities in each zone should be summarized into a simple activity/zoning matrix; Figure 2 shows the GBR zoning matrix.			
16. **Traditional and local knowledge.** Use, embrace and acknowledge the special knowledge that many MPA users have, combining such knowledge with that of managers and professional researchers to design and implement a zoning plan.	Those who are frequently on the water (including commercial and recreational fishers, tourist operators and Traditional Owners) have a different perspective and invaluable knowledge about the local marine environment, which can complement the knowledge of managers and researchers. MPA planners should draw upon this knowledge and use it to augment the best available scientific data. Additionally, such users of the MPA are likely to have more ownership and offer subsequent support of the zoning outcomes if they have opportunities to be involved throughout the zoning process and can see evidence that their input has been appropriately considered.	X	XX	XX
17. **Decision support tools.** Analytical tools may prove helpful but are not an essential requirement to undertake a comprehensive zoning programme.	Decision-support systems (DSSs) or analytical tools (such as Marxan, MarZone or SeaSketch) are often promoted as a prerequisite for effective marine spatial planning. Many planners hope that using a DSS will generate 'the answer', providing a quick and reliable solution to their planning problem. All DSS tools have limitations and cannot compensate for missing or incomplete data or for a lack of political feasibility. Planning outcomes are of little practical value if social, cultural and economic values are not responsibly considered. However, rarely are such data readily available at an appropriate spatial resolution or in a form amenable for use in a DSS. DSSs are rarely able to match the complexity of real-world planning problems and can also produce unintended side effects, so the results they generate usually need to be modified using other planning methods. For these reasons, DSSs will seldom, if ever, produce the final pragmatic solution for any planning task (Day et al., 2004; Lewis, Day, Fernandes, Lowe, & Slegers, 2007).	X	XX	-
18. **Placement of zones and zone boundaries.** Where zone boundaries are placed should consider ease of public understanding and consequent compliance.	As far as is practicable, zone boundaries (as well as MPA boundaries) should be readily available to users as well as recognizable while on the water. Without these considerations, public understanding and compliance[a] with zoning may be difficult. In some instances, physical demarcation of zone boundaries may use fixed markers on the land or floating marker buoys, but there are significant costs to install and maintain such infrastructure and issues with flawed interpretation of the boundary (e.g. marker buoys move depending on tidal flows and depth). Traditionally, inshore MPA	X	XX	X

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
	boundaries were referenced to an obvious natural feature or by using a specified distance from a feature like the shoreline but this may be confounded by varying tide levels or uncertainty as to where the shoreline precisely occurs. Experience has shown that submerged features (e.g. depth contours, reefs, shipwrecks) may be even harder to identify, so they should not be used as a basis for determining marine boundaries (Lesson 22 explains how coordinate-based boundaries are able to address many of these issues).			
19. **Avoid sudden transitions** between levels of protection offered by different zone types when zoning.	A multiple-use zoned MPA should avoid sudden transitions from highly protected areas to zones of relatively little protection; the concept of 'buffering' (i.e. having a gradation of zone types) should be applied wherever possible (Day, 2002). The adoption of this principle theoretically strengthens the ecological integrity of the highly protected areas, including through reduced enforcement and compliance risk.	–	XX	XX
20. **Discourage vertical zoning** in the water column, for both ecological and compliance reasons.	Some MPAs have formally applied vertical zoning, allocating part of the water column to a different zone from that of the sea floor (e.g. allowing pelagic fishing in the water column but prohibiting benthic fishing). There is uncertainty in the way benthic and pelagic systems and species interact, and researchers are only just beginning to understand how surface or mid-water fisheries may in fact be ecologically connected to benthic communities below. Furthermore, enforcing vertical zoning is extremely difficult. The three-dimensional nature of the marine environment can still be recognized by designating a single zone that clearly stipulates what can and cannot occur throughout the entire water column, e.g. the Habitat Protection Zone in the GBRMP.	X	XX	XX
21. Zoning in or around **ambulatory coastal features** (e.g. sand spits or shallow bays) needs to better consider the transient nature of such features.	Shorelines may be ambulatory (i.e. erode and/or accrete), so management boundaries may be difficult to understand or enforce if they move or are difficult to define. Any zoning adjacent to ambulatory coastal features needs to address the transient nature of such features. (Lessons 21 and 22 are further explained for the GBR in Supplementary Information Table S5)	*X	*XX	* XX
22. **Coordinate-based boundaries** for describing zones.	In deep water, for open-ocean conditions or for large MPAs, the placement of marker buoys for zone or MPA boundaries is extremely difficult, if not impossible, and the cost is prohibitive. For these reasons, MPA managers usually delineate such offshore boundaries using coordinates and a Global Positioning System (GPS) (see Figure 3b and GBRMPA, n.d.). Coordinate-based boundaries are relatively easy to locate and enforce in offshore areas using electronic devices, e.g. a GPS device or plotter.	–	X	XX
23. **Benefits of zoning.** Zoning can lead to substantial ecological and economic benefits provided it is appropriately developed and then implemented.	As discussed in Lessons 4 and 5, ensuring representative examples of all mapped bioregions in no-take zones has increased protection for the full range of biodiversity in the GBR (including features not known at the time of zoning). Significant ecological outcomes have occurred (some relatively quickly) following declaration of the zoning plan (e.g. Russ et al., 2008). Mellin, MacNeil, Cheal, Emslie, and Caley (2016) have demonstrated that MPAs can increase the resilience of coral reef	X	XX	XX

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
	communities to disturbances such as coral bleaching, coral disease, *Acanthaster planci* outbreaks and storms. Lesson 35 also outlines the importance of monitoring these outcomes.			
24. Zoning has been shown to have **spillover benefits for fisheries**, even if the protection of biodiversity is the main objective.	The spillover benefits of the no-take zones in the GBR has been demonstrated for some species (e.g. coral trout) by Williamson, Russ, and Ayling (2004) and Harrison et al. (2012). Nevertheless, it is important to recognize that most fisheries are complex social–ecological systems, and changes in management, policy, economics or the environment can all affect the way fishing occurs, as well as the benefits it delivers and the impacts on other users and the environment (Chin, Cameron, & Saunders, 2019; Sutton & Tobin, 2012).	X	XX	XX
25. Although zoning cannot encompass the full life cycle of many **migratory species**, the benefits of zoning for these species is becoming increasingly recognized.	Research is increasingly recognizing the appropriateness of zoning for migratory species (e.g. Schofield et al., 2013; Scott et al., 2013; Sibert, Senina, Lehodey, & Hampton, 2012; Stokes, Boersma, de Casenave, & García-Borboroglu, 2014). It is difficult to quantify these benefits, but the fact that some migratory species temporarily have high site fidelity at important stages of their life cycle is an indication that highly protected areas can mitigate risks for some migratory species (Tobin et al., 2014).	X	XX	XX
26. **Climate change.** Given its widespread global impacts, climate change should be explicitly considered in any zoning.	Climate change is rapidly emerging amongst the biggest threats facing MPAs, so it needs to be addressed as a key aspect of marine management. Highly protected zones are likely to be more resilient, and therefore better able to cope with the impacts of climate change or other pressures in the longer term (see also Lesson 27).	X	XX	XX
27. **Highly protected zones are still subject to impacts**, including climate, but are likely to remain a valuable MPA management tool for ecological resilience.	The back-to-back bleaching in the GBR in 2016–2017 showed that reefs in all zones bleached, irrespective of the underlying level of protection (Hughes et al., 2017). What remains unclear is the extent to which more highly protected areas may be more resilient, and therefore able to recover more quickly (or more readily) given their level of ecological coherence. Climate change, therefore, needs to be explicitly considered in any zoning or rezoning.	X	XX	XX
28. **Unique zone identifier.** Having a unique identifier for every single zone has many advantages.	Providing every individual zone in the MPA with its own unique zone identifier enables users to find out more information if required, linking each zone to additional information provided elsewhere, e.g. in the zoning plan, on the internet, or in a document justifying the zoning decisions (see Lesson 36). Figure 4 shows examples of zone identifiers on zoning maps.	—	XX	XX
29. **Zoning information widely and freely available.** Need to ensure that information about the locations of all zones and what are the appropriate activities for each zone is freely available in formats accessible to all key stakeholders and rights holders.	To be effective, all aspects of the zoning (such as zone locations, allowable provisions, prohibited activities, etc.) need to be readily available for all users. A zoning plan is only as good as the stakeholder, community and wider public support that it enjoys. In the GBR, zoning maps are made freely available in numerous centres and shops along the GBR coast. However, not every aspect of spatial management is shown in the zoning maps. The internet is also an important source of information;	X	XX	XX

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
	the unique zone identifier (see *Lesson* 28) helps to provide specific information for specific locations.			
30. **New and emerging technologies.** A zoning plan should consider all known uses but also have provisions to be able to assess new technologies or new activities.	Part 3 of the GBR Zoning Plan outlines two lists that encompass all the known activities able to occur in a zone in the GBR (with or without a permit). However, technology is always changing, so the GBR Zoning Plan has a special 'catch-all' permit provision ('any other purpose consistent with the objective of the zone …'). This provision provides for new technologies or activities that were not known when the zoning plan was approved and therefore are not in either of the lists. If assessed to be consistent with the relevant zone objective (see Table 1), an activity that is not specifically listed may still be assessed and may be granted a permit. This provides an important 'safety net' enabling previously unknown activities to be considered for a permit.	—	X	XX
31. **Permits.** These (often tied to specific zones or locations within zones) allow a detailed level of spatial management not possible by zoning alone.	Having a zoning plan does not necessarily equate to effective management, and many other management tools in the manager's 'toolkit' can more effectively address the issues impacting marine conservation (see Supplementary Information Table S5). When a permit is issued, it usually has detailed conditions that specify when, where and how the activity can occur (not necessarily throughout the zone) and further specifies management requirements to ensure any environmental impacts remain at acceptable levels. A permit remains valid for a specified period, after which it expires unless it is renewed.	—	XX	XX
32. **A permit is not guaranteed.** A zoning plan may indicate an activity can occur if granted a permit, but that does not automatically mean a permit will or should be granted for that activity.	This misconception may be best illustrated by another example using the Habitat Protection Zone in the GBR. Activities such as aquaculture or harvest fishing that may or may not have an impact *may* be permitted to occur in that zone but only after undergoing a comprehensive permit assessment process. The assessment determines whether the specific proposal (such as the actual aquaculture method or proposed location of the harvest fishing) is compatible with the zone objective and meets all the necessary permit criteria. Once the necessary requirements in the assessment process have been satisfactorily addressed, a permit may be issued.	—	XX	XX
33. **Adequate resourcing.** Ongoing and adequate resourcing, particularly for compliance activities, is essential to ensure the effectiveness of zoning and maintain the flow-on social and economic benefits.	Ongoing and adequate resourcing is essential to ensure a zoning plan is effective; for example, a well-resourced and ongoing compliance programme, including enforcement (see Footnote a in the Table legend), is essential, as is ongoing community engagement in the management of the zoning plan. This should include an effective communication and education campaign to ensure ongoing zoning awareness. Ongoing management is required, not just for the conservation benefits for the ecosystem, but equally the flow-on social and economic benefits for adjacent communities and industries—including all the industries that rely on the MPA for their livelihoods. (See Supplementary Information Table S5 for more details.)	X	XX	XX

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
34. **No rotational opening of zones.** No-take zones declared for biodiversity protection should not be periodically opened to allow fishing and then closed (i.e. no rotational opening and closing).	Highly protected zones that prohibit all fishing and collecting need to be in place for the long term given their role to protect all species and habitats, not just fished species. The benefits (both within the zone and also as spillover to adjacent areas) become greater the longer those areas are left closed to extractive activities (e.g. Harrison et al., 2012; Russ et al., 2008). If an area that has been highly protected is subsequently opened to fishing, it can quickly become targeted and rapidly become depleted (Supplementary Information Table S5 provides more information).	—	XX	XX
35. **Comprehensive monitoring and evaluation system**. Any zoning should be monitored and periodically reviewed and adapted given that the context and the pressures are likely to change.	Robustly-designed monitoring is a fundamental management tool to document environmental condition, natural and anthropogenic impacts and to assess the effectiveness of management actions, including zoning. Monitoring is needed to show whether the zoning is achieving (or not) its objectives and is an important prerequisite for adaptive management. Managers should use monitoring to report back to local communities, stakeholders and decision-makers on performance. Key monitoring questions include what is an adequate level of monitoring, but also who is best suited to undertake such monitoring. There may be a need to monitor both within a zone and outside the zone (i.e. compare the zone with a control site); and recognize the issue of 'shifting baselines' if the monitoring is not effectively recorded. It is critically important that the monitoring and assessment of the results, followed by public communication of these results, are built into the postzoning implementation and available for assessments and outlook reporting (GBRMPA, 2009, 2014). This is especially important at the local or regional scale for securing political support for ongoing management and future amendments/rezonings.	*	X	XX
36. **Documenting the reasons** behind all the zoning decisions—both thematically and by location.	A report outlining the basis for zoning decisions (both thematically and by location) is invaluable to justify to different stakeholder groups why a particular area/reef was zoned the way it was. Such a compilation (e.g. GBRMPA, 2005) is helpful during implementation but will also undoubtedly be useful in any subsequent zoning review.	*	*X	XX
37. **Reviewing existing zoning.** Comprehensive zoning should be periodically reviewed, updated and/or adapted given the likely numerous changes occurring in and around the MPA.	Zoning is certainly an important management tool for effective ecosystem-based management. However, to remain effective, zoning must be periodically reviewed, especially considering the enormous changes occurring in most MPAs, including rapidly changing patterns of use, technological changes, social–economic changes, political changes, and, most importantly, recognizing that marine ecosystems are dynamic natural systems, subject to a myriad of environmental (including climatic) changes and new discoveries (e.g. Harris et al., 2013).	*	*XX	*XX
38. Setting a **specific or set timeframe** within which a zoning plan should legally be reviewed is unnecessary. What should occur is a willingness to review and adapt zoning when clearly the circumstances in or around the MPA have changed.	Any successful management regime must be adaptable and be able to incorporate new information as it becomes available or as circumstances change. Irrespective of whether a change in marine management results from new data, 'in-the-field' experience, or as a result of external circumstances, all management arrangements must be periodically	—	X	XX

(Continues)

TABLE 6 (Continued)

Generic zoning lessons learned	Notes and clarification	Before zoning	During zoning	Implementing a zoning plan
	reviewed and updated to ensure they continue to address problems and deliver ecologically sustainable solutions. Some legislation stipulates a set timeframe when a review of marine management is required; in contrast, the GBRMP Act determines a minimum timeframe for which zoning must remain in force; this approach is intended to give certainty to users (see Supplementary Information Table S5 for more details).			

Supplementary Information Table S5 provides detailed experience from the GBR against each of these generic lessons.

XX: Lesson highly relevant to this phase; X: lesson of some relevance to this phase.

*Lesson may, or may not, be applicable when zoning; —: NA.

[a]A comprehensive compliance programme involves a much wider range of activities than just enforcement; it includes activities such as targeted education, surveillance, field patrols, intelligence, audit, investigations, prosecutions and formal directions/orders/sanctions.

though the waters within these areas may influence GBRMP waters. Two such ports are shown as small coastal exclusions bounded by the red lines on the maps in Figure 5a–d; the larger exclusion is the Port of Townsville.

6 | KEY LESSONS LEARNED AND MISCONCEPTIONS ABOUT ZONING

Previous publications have addressed various lessons about zoning in the GBR:

- Day (2002) identified zoning aspects that had worked well in the GBR, aspects that had changed (or were being changed) and various other zoning lessons.
- Fernandes et al. (2009) addressed the important role played by applying the biophysical operating principles in the GBR rezoning.
- Kenchington and Day (2011) addressed six misunderstandings about the management of the GBR, particularly around zoning.
- Day (2016) identified 12 lessons learned about zoning and MSP, along with some challenges for other MPAs and MPA networks.

6.1 | Generic zoning lessons learned

After 40 years of 'learning by doing' in the GBR (i.e. adaptive management), many important lessons have been learned. Building on the above publications, Table 6 lists 38 generic lessons about zoning. The numbering sequence of the lessons does *not* reflect any priority of importance; however, the three columns on the right-hand side of Table 6 indicate at which of the following phase(s) of a zoning programme the lesson should be considered:

- *before* commencing a programme of zoning; and/or
- *during* the development of a zoning plan; and/or
- effectively *implementing* a finalized zoning plan.

Many of the lessons listed need to be considered primarily at one specific phase of a zoning programme (and where a lesson is highly relevant, it is shown by XX in the table). However, a number of these lessons (e.g. zoning is not the only management tool; effective public engagement; the role of politics and politicians) need to be considered throughout all three phases of a zoning programme.

In some instances, limited information from the GBR is provided in the *Notes and clarification* column against these lessons. However, far more detailed and specific information about the GBR against each of these same lessons is provided in a similar table (see Supplementary Information Table S5).

6.2 | Misconceptions about zoning

In addition to the aforementioned lessons, planners need to be aware that there are many misconceptions about what zoning means or what it does. For example, some of the more prevalent misconceptions include:

- *Only no-take zones play a role in biodiversity conservation* (the reality is that other zones, e.g. the Habitat Protection Zone and Conservation Park Zone, have been shown to play important roles (e.g. Boaden & Kingsford, 2015).
- *Scientific research can only occur in formally declared Scientific Research Zones* (there is no reason why scientific research, if carefully controlled using a research permit, should not be able to occur in all zones).
- *Zoning is only aimed at stopping fishing* (on the contrary, most zoning specifically aims to protect a wide range of biodiversity but has been shown to lead to spillover benefits for adjacent fishing zones).

These misconceptions, and others, are more fully explained in Supplementary Information Text S3.4.

7 | CONCLUSIONS

The application of zoning in the GBRMP undertaken over the last four decades, along with a variety of other spatial and temporal tools that complement the underlying zoning, provide useful lessons for effective marine management both in the GBR and elsewhere. The multiple-use zoning scheme remains one of the key foundations for managing the GBR, especially as the integrated governance and management model aims to addresses cross-jurisdictional marine and terrestrial considerations for state and federal waters.

The value of this integrated ecosystem-based approach for the management of the GBRMP is now widely acknowledged. Nonetheless, the unfortunate reality is that the GBR is suffering from cumulative impacts beyond the direct jurisdictional coverage of marine zoning (Halpern et al., 2008). Terrestrial runoff (Brodie & Waterhouse, 2012), coral bleaching due to pressures like ocean warming and increased severity of the extreme storm events (Heron et al., 2017) associated with climate change are among the primary pressures, but clearly only a few of the many threats outlined in the 2014 Outlook Report (GBRMPA, 2014).

The 2003 GBR rezoning was completed prior to the current level of awareness of the impacts of climate change for marine ecosystems. These impacts, particularly for coral reefs, have been dramatic in recent times. The latest research is revealing that impacts associated with climate change (bleaching, acidification, storm damage, increased disease) will significantly and drastically undermine resilience in the coming decades at least. In the light of this knowledge, there is a consequent and urgent need to minimize global emissions as well as address other more local threats to ecosystem health and function, with the GBR *Blueprint for Resilience* (GBRMPA, 2017) promoting a range of interventions and actions targeting coral reefs in the context of a changing climate. Furthermore, the role that zoning might play in such actions, and particularly recovery after such afore-mentioned impacts, requires monitoring and assessment.

The *Reef 2050 Plan*, the government's plan for protecting and managing the GBR until 2050, is currently under review as the initial 2015 plan was criticized for failing to provide a sound basis for the necessary long-term protection of the GBR. These initial criticisms included a failure to effectively address climate change (given it is now clearly recognized as the biggest threat), and insufficient measurable or realistic targets to enable monitoring and reporting on the plan's implementation.

Some of the most rapid changes with implications for zoning in the last decade have arisen through technological advances for users and managers alike; these will undoubtedly continue to change, but the implications for zoning can be a 'double-edged sword'. For example, technology can provide greater certainty about the location of zone boundaries, but this also means users can easily and efficiently target fish aggregations or optimal fish habitat. However, it is foreseeable that improvements to technologies will enable better awareness of MPA usage patterns and for users to receive an alert (e.g. on their mobile phone) if they enter a highly protected zone or other restricted area.

The 'contemporary best practice' planning process used by the GBRMPA to develop the 2003 GBR Zoning Plan (e.g. ongoing public engagement; political involvement) drew on previous GBR and international experience to provide the key components of the current management approach. Decades of experience of 'adaptive management' and 'adaptive planning', within the GBR and elsewhere, have influenced ongoing experience of marine conservation efforts (see other zoning efforts listed in Supplementary Information Table T1).

The adaptive management approach as applied in the GBR has been a major contributor to the overall management success; key components of this adaptive management approach include:

- key policies and position statements[5] (i.e. specifying locally appropriate actions based on a sound understanding of the system's status and behaviour);
- management systems that implement those policies;
- partnerships with others where responsibility is shared; and
- monitoring plans to determine system responses and provide a basis for adjusting management.

Any successful management regime must integrate all these four aspects 'on the ground' (e.g. both the policy and the implementation/management aspects need to work together). All management practices need to be periodically reviewed and updated where appropriate (see Table 6, Lesson 37). Furthermore, management must be able to incorporate changes, such as new information becoming available or as circumstances change. Adaptive management enables managers to be flexible and to expect, and deal with, the unexpected (e.g. climate change was not considered an important marine issue in the early 2000s).

It is impossible to determine what would be the current state of the GBR if the multitude of management actions, including zoning, had not been applied over the past 40 years. However, without the variety and level of management that has occurred, and particularly zoning, it is highly likely that more of the GBR values would be considerably degraded (Day, 2017b).

As outlined in this paper, it is unlikely that any zoning plan can be optimally effective for more than a decade or two given the number of changes happening in and around all MPAs (i.e. environmental, social, economic, technological and political changes). Significant changes have occurred in the GBR since the adoption of the 2003 zoning plan, so a review of that plan would not be unexpected. A precursor to such a review may well be a broad assessment of the existing GBR zoning and its effectiveness to achieve the legislative objectives; this could be linked to a periodic reporting process such as the five-yearly *Outlook Report* (see Supplementary Information Table S6).

The lessons, suggestions and misconceptions about zoning discussed in Table 6 should be useful for both new and existing MPAs; however, the following nine broad groupings of zoning lessons should

[5]A position statement differs from a policy and outlines an agency's position on an issue where it has a strong interest, but where that particular issue is outside its direct regulatory control. For example, the GBRMPA has a position statement regarding the management of coastal ecosystems and another about aquaculture operations. Other government agencies, departments and industries are therefore clear on GBRMPA's views in relation to that issue, especially regarding matters such as water quality likely to affect the resilience and management of the GBRMP.

be regarded as the most important, particularly for first-time marine planners or decision-makers who are contemplating an initial zoning programme, but also for those who need to review their zoning where it has been evolving for some time:

1. Zoning is not the only management tool in the marine manager's toolkit—and zoning should be used in conjunction with other spatial and temporal management tools (see Lesson 1, Table 6).
2. An effective zoning plan should be developed and implemented using the best available knowledge, but it should not rely upon nor wait for comprehensive data collection and analysis. Utilizing local knowledge and informed judgement should be used to develop fit-for-purpose zoning (Lessons 3 and 16).
3. Ensuring community and political understanding, involvement and acceptance of final zoning options will be enhanced by effective public engagement, including the development of a publicly available zoning plan (Lessons 9, 10, 18 and 29).
4. If there are differing jurisdictional responsibilities in adjoining waters, complementary zoning across jurisdictions is strongly encouraged (Lesson 14).
5. Zoning should be based upon clear overall MPA objectives and clear zone objectives, rather than zoning for single activities (Lesson 15).
6. Marine users, but especially fishers, are likely to be influenced and affected by any zoning programme. The responsible acquisition and incorporation of all available data on such activities is critical in the design, implementation and stakeholder acceptance of any zoning programme (Lesson 16).
7. The placement of zone boundaries needs to consider ease of public understanding and consequent compliance. This should include inshore zone boundaries that are readily identifiable without a GPS device, as well as coordinate-based boundaries for zones in open-ocean conditions or in large MPAs (Lessons 18, 19, 20 and 22).
8. Provided zoning is effectively developed and implemented, it can play a significant role in separating competing uses or regulating uses, contributing to building resilience and ensuring the ecological sustainability of the entire marine ecosystem (Lessons 23, 24 and 27).
9. The task is not completed once a zoning plan comes into law. The ultimate success of a comprehensive zoning plan requires concurrent development and consequent implementation of custom-made and prioritized monitoring and compliance programmes as well as community engagement programmes (Lessons 33, 35, 36 and 37).

Zoning, as with most aspects of protected area management, will only be effective if it is well implemented with strong monitoring and compliance, and reporting of performance (e.g. GBR Outlook Reports in 2009 and 2014). Simply putting lines on maps or drawing zones, no matter how scientifically well designed, will not protect the ecosystem in the absence of effective management—An otherwise elegantly designed plan may end up existing mainly 'on paper'.

It is important to recognize, however, that what has worked in the GBR will need to be customized for other marine jurisdictions (Day, 2011). Other marine ecosystem-based management/zoning/conservation initiatives have different management history, contexts, models and objectives. It is therefore essential to consider the specific political, economic, social and managerial contexts when translating the zoning lessons from the GBR to other areas.

Marine zoning remains a fundamental component to help address the multitude of ocean challenges facing the world today and into the future. Effective zoning is, therefore, a key requirement to achieve ecosystem-based management. We hope that this paper will be useful for practitioners, planners, managers and decision-makers aiming to utilize marine zoning to achieve effective marine conservation and protection as well as ecologically sustainable use.

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DISCLAIMER

The views expressed in this paper are those of the authors alone; they do not necessarily represent the views of any agencies, organisations or institutions with which the authors have been, or are affiliated.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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