So excellent a fishe: a global overview of legal marine turtle fisheries
Frances Humber, Brendan J. Godley and Annette C. Broderick

ABSTRACT
Aim We provide a global assessment of the current legal direct take of marine turtles, including the scale and species breakdown at country level, and investigate the significance of legal take to marine turtle populations within the wider context of global threats.

Location World-wide.

Methods We undertook a comprehensive review of the literature (> 500 publications) and contacted over 150 in-country experts to collate data for countries that permit the legal take of marine turtles (as of 1 January 2013). Current annual take for each country and species was estimated, and estimates were generated for the 1980s, 1990s and 2000s.

Results Currently, 42 countries and territories permit direct take of turtles and collectively take in excess of 42,000 turtles per year, the majority of which (> 80%) are green turtles Chelonia mydas (Linnaeus 1758). Ten countries account for more than 90% of legal take each year with Papua New Guinea (36.1%) and Nicaragua (22.3%) accounting for more than half of the total global take. Since 1980, we estimate that more than 2 million turtles have been legally taken in these countries, with current levels < 60% of those in the 1980s.

Main conclusions Our results provide the most comprehensive global synthesis of the legal take of turtles in recent years and suggest that legal take has the potential to be a driver of marine turtle population dynamics, comparable to mortality estimates through recorded bycatch. However, it is likely that illegal take, along with bycatch, is significantly under-recorded and far greater than the total level of directed legal take. This hampers the ability to assess the relative impacts of these threats to marine turtles.

Keywords Direct take, global, legal fisheries, legislation, marine turtle, traditional fisheries.

INTRODUCTION
Widescale commercial exploitation is thought to have contributed significantly to the global decline in marine turtle populations (Lewis, 1940; Stoddart, 1980; Jackson, 1997; National Marine Fisheries Service & U.S. Fish and Wildlife Service, 1998; Broderick et al., 2006; Cornelius et al., 2007) leaving many populations at relictual levels (Pritchard, 2003; McClenachan et al., 2006; Bell et al., 2007). However, the direct take of nesting and foraging marine turtles for meat, shell and other products has taken place for millennia (Groombridge & Luxmoore, 1989; Frazier, 2003; Daley et al., 2008). Artisanal and subsistence take, as part of longstanding traditional fisheries, primarily for local consumption, may historically have been at more sustainable levels (Frazier, 1980), but levels of exploitation increased radically upon western colonization of the New World (Babcock, 1938; Wayne King, 1995; Mrosovsky, 1996). Quickly, some of this take proved unsustainable, with the first marine turtle harvest legislation instigated in Bermuda in 1620 to protect ‘...so excellente a fishe...’, prohibiting taking any turtle ‘under Eighteen inches in the Breadth or Dyameter’ (Babcock, 1938; Godley et al., 2004).
Notwithstanding, large-scale commercial take in areas with remaining abundance continued, with global capture peaking at over 17,000 tonnes in the late 1960s (FAO, 2011), principally fuelled by commercial-scale exploitation and international trade (Fleming, 2001; van Dijk & Shepherd, 2004). For example, during the peak of Mexico’s sea turtle exploitation in 1968, it is estimated that the national take was over 380,000 turtles (Cantú & Sanchez, 1999). The continued international trade of turtle products in the latter half of the 20th century meant that over 2 million turtles (hawksbill *Eretmochelys imbricata*, Linnaeus 1766; green *Chelonia mydas* and olive ridleys *Lepidochelys olivacea*, Eschscholtz, 1829) would have been needed to produce the volume of marine turtle products imported into Japan between 1970 and 1986 (Milliken & Tokunaga, 1987). Against the backdrop of widespread commercial exploitation, a decline in traditional and small-scale turtle fisheries also occurred (Frazier, 1980; Allen, 2007; Bell et al., 2010), resulting from increased pressures from human populations and more efficient capture methods (Brikké, 2009), often with a corresponding breakdown of associated cultural rituals that would have once promoted more sustainable take levels (Hickey, 2003; Allen, 2007).

Increased conservation awareness at the international scale has led to greater protection of marine turtles and a series of multilateral agreements with associated enabling local legislation coming into force to restrict the trade of turtle products, such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1975, which helped to reduce demand and promote regional cooperation in increasing turtle populations. By 1980, 59 countries were signatories to CITES rising to 178 in 2013, and although subject to considerable debate, marine turtle species have been listed on the IUCN Red List of Threatened Species since 1982 (Mrosovsky, 2003; IUCN, 2013).

Despite increasing levels of protection, the direct take of turtles has continued legally in many regions and countries (Bräutigam & Eckert, 2006; Aylesworth, 2009; Maison et al., 2010). Permitted take now tends to be characterized by subsistence use by traditional coastal groups, or small-scale fisheries supplying local markets with meat, and sometimes shell (Bräutigam & Eckert, 2006; Limpus, 2008; Maison et al., 2010). The fisheries continue to be an important source of finance, protein and cultural identity in these parts of the world (Hamann et al., 2006; Vander Velde, 2008). Although the nature of these permitted fisheries vary greatly among countries and regions, many have been subject to increasing regulations over the past 30 years, with specific legislation put in place to help manage direct take, often limiting species, number, timing or size of turtles targeted (Bräutigam & Eckert, 2006). There is, however, a paucity of information on the direct take from these fisheries at present, despite often being listed as one of the major threats to marine turtle populations (Wallace et al., 2010; IUCN, 2013). Here, we set out to assess the current legal direct take (hereafter referred to as legal take) of marine turtles globally; as well as recent trends within those countries.

### METHODS

#### Focal countries

In this study, we focussed on coastal countries or territories, hereafter referred to as countries, which currently (as of 1 January 2013) permit the legal take of marine turtles and are geographically between 40°N and 40°S. This region covers the majority of the known range of hard-shelled marine turtle species (IUCN, 2013). Although some marine turtle species can occur outside this range, there is no significant direct turtle take documented outside these latitudes. Legalized egg harvest was not included in this study.

The national legislation within these countries was further classified as allowing marine turtle take if protection was absent, unverifiable, incomplete or temporary. National legislation was classified into one of five categories: protection absent (N), legislation allows for a level of directed take of one or more species of turtles (L), full protection but traditional hunting exemptions exist (T), moratorium in place at present (M) and unable to verify legislation (U).

#### Data compilation

We searched relevant databases (e.g. Web of Knowledge, Google Scholar, seaturtle.org, Sea Turtle Bibliography at the Archie Carr Center for Sea Turtle Research, SPC Coastal Fisheries Programme) and the broader internet using combinations of relevant keywords (‘turtle’ with ‘take’, ‘harvest’ or ‘fishery’). Over 500 reports and papers were collated and reviewed to compile data on legal take, with bycatch or incidental take data removed where possible. In the first instance, data from actual studies were prioritized, but in the absence of such data estimates by experts found in the literature or via personal communications were used. Where data presented in the literature were unclear or incomplete, efforts were made to consult relevant authors. Further consultation with expert individuals living in or known to work in target nations (> 150 contacted by email; 106 responded with information) was undertaken to locate further reports and papers and ascertain best estimates of legal take since 1 January 2010.

Data for all seven species of marine turtles (green; hawksbill; loggerhead *Caretta caretta*, Linnaeus 1758; olive ridley; leatherback *Dermochelys coriacea*, Vandelli 1761; Kemp’s ridley *Lepidochelys kempii*, Garman 1880; flatback turtle *Natator depressus*, Garman 1880), were collated by country (see Table S1 in Supporting Information; Appendix S1).

A median was calculated for any estimates given as ranges. Where a single estimate was provided as an annual estimate for a number of years, the same value was used for each year in the range. Estimates given as a total figure for a number of years were divided equally among those years. Multiple estimates by different authors for the same year were averaged. No attempt was made to extrapolate data where estimates were given for periods less than a year, or when they...
were not countrywide estimates. In these cases, values were included as minimum values.

In a small number of highlighted cases (Table S1; n = 8), international trade statistics in bekko (hawksbill turtle shell) were used to calculate estimates for hawksbills, only where no other data could be located. Conversions rates of bekko (kg) to number of turtles were normally given by authors (e.g. Fiji 0.7–1.1 kg bekko/turtle, Milliken & Tokunaga, 1987).

Creating annual estimates for each decade

We calculated the median annual take for each decade (1980s, 1990s and 2000s) for each species by country and for our current estimate the median annual take for the years 2010–2012.

Data that had not been identified by species were only included in circumstances where we were confident that the data were not duplicated within other studies. Data were then broken down into species using the best available species composition information from additional studies and reports from that country.

Where data were missing for a decade, we used the temporally closest data to extrapolate. For example, where we only had data for the 1990s and 2000s, we used the 1990s estimate for the 1980s. Where decadal data were only available for the 1980s and 2000s (n = 4 countries), we used what we considered would be the most similar estimate for the 1990s, in relation to any changes in legislation or reports of increases/decreases in legal take. Where data for only one decade existed (n = 8 countries), this was used for all other decades. To allow confidence to be assigned to overall estimates, any ‘estimated’ data are highlighted.

Current take

Relevant expert individuals contacted between 2011 and 2013 were also asked for comments on present-day harvest compared with the last known study or report on take within a country. If the expert was unable to answer or unable to confirm, then take was assumed to have been unchanged from the most recent known estimate.

RESULTS

Legislation

As of 1 January 2013, a total of 42 countries permitted the direct take of marine turtles, four countries had a moratorium on take (Anguilla, Chile, Fiji and the Maldives), although permits for traditional purposes can be granted in Fiji; and four countries had legislation that could not be verified (Algeria, North Korea, Panama and Somalia) (Fig. 1) (see Table S1 for information on type or absence of legislation). A change of legislation to prohibit direct turtle take occurred in three countries (Republic of Congo, South Korea and Trinidad and Tobago) between 1 January 2010 and 1 January 2013. Data from these countries, and also those that prohibited turtle take between 1980 and 2010, are not included in this study.

Take by species

We estimate that currently, more than 42,000 marine turtles are caught each year as legal take (n = 42 countries). Over 80% of these are green turtles (37,339; 88.5% of catch), with an estimated 3456 hawksbill turtles taken each year (8.2%) (Fig. 2). Fewer than 1500 loggerhead (1051; 2.5%), leatherback (62; 0.1%) and olive ridley (263; 0.6%) turtles are estimated to be among those legally captured each year. Data on take of flatback turtles were scarce with only a small amount recorded from Papua New Guinea and Australia, approximately 18 turtles year⁻¹ (Kare, 1995; Kennett et al., 1998). No data were found on legal take of Kemp’s ridley turtles from 1980 to present day.

Green turtles were the only species permitted to be taken from all countries within this study, with the exception of countries with a moratorium (although not including Fiji).
Leatherbacks had the highest degree of protection and were prohibited from take in 13 of the 42 focal countries examined (31%).

**Global distribution of take**

Current permitted take is concentrated in two regions: the wider Caribbean region accounts for 34.6% (14,640 turtles year\(^{-1}\)) of estimated take from 16 countries (see inset Figs 3 & 4a) and the Indo-Pacific region accounts for 63.3% (26,675 turtles year\(^{-1}\)) from 17 countries (Figs 3 & 4b). No take was known to occur in four of the countries where it was legal (Bosnia and Herzegovina, Niue, Pitcairn Islands and Wallis and Futuna). In 12 countries, take was unquantified: in three of these countries, take was known to occur but no estimate was available (Kiribati, Nauru and Syria), and nine of these countries only illegal take data were found (Belize, Cayman Islands, Dominica, Indonesia and Atlantic coast of Mexico), including four countries where a moratorium exists (Anguilla, Chile, Fiji and Maldives). Take from the four countries where legislation could not be verified (Algeria, North Korea, Panama and Somalia) is estimated to be 6700 turtles year\(^{-1}\) and is not included in the 42,000 estimate (Table S1). A breakdown of take by species for each country is available in Figures S2, S3 and Table S1.

**Take by country**

The top ten countries with permitted take account for 94.2% (39,716) of marine turtle take per year (Fig. 5). Papua New Guinea (15,217 turtles year\(^{-1}\); 36.1%), Nicaragua (9413 turtles year\(^{-1}\); 22.3%) and Australia (6638 turtles year\(^{-1}\; 15.7\%\)) together account for almost three-quarters of current permitted take (74.1%; 31,268). Given the preponderance of green turtles, the top ten countries for this species are similar to those for overall take. Papua New Guinea, Australia and Nicaragua do not feature in the top four species, apart from a small annual take of hawksbills from Papua New Guinea and Australia and a small annual take of loggerheads from Australia (Figure S4).

**Past take**

The estimated change in annual permitted take of marine turtles in 46 countries that currently allow take of turtles (including the four with current moratoria) over the past 3 decades is illustrated in Fig. 6 and by species in Figure S1. We estimate that more than 2 million turtles have been taken by these countries since 1980. Take has decreased by more than 60% over the past three decades, from an estimated take of 116,420 turtles year\(^{-1}\) in the 1980s,
Figure 4 Estimated annual current legal marine turtle take for (a) the Caribbean and (b) the Pacific regions highlighted in Fig. 3 (data from 1 January 2010 to 1 January 2013). No take = no known legal or illegal take; Unquantified take = illegal take data found only or take known to occur but no data available. *Country with moratorium. Country abbreviations (countries in brackets indicate dependency): (a) ANG = Anguilla (UK); ANT = Antigua and Barbuda; BEL = Belize; BRI = British Virgin Islands (UK); CAY = Cayman Islands (UK); COA = Colombia (Atlantic coast); DOM = Dominica; GRE = Grenada; HAI = Haiti; HON = Honduras; MON = Montserrat (UK); NIA = Nicaragua (Atlantic coast); STK = St. Kitts and Nevis; STL = St. Lucia; STV = St. Vincent and the Grenadines; TUR = Turks and Caicos. Take is also shown for countries with unverified legislation: PAA = Panama (Atlantic coast). This take was not included in grouped take CAR in Fig. 3. Country abbreviations (countries in brackets indicate dependency): (b) COO = Cook Islands (New Zealand); FIJ = Fiji; NAU = Nauru; NEW = New Caledonia (France); NIU = Niue; SAM = Samoa; SOL = Solomon Islands; TOK = Tokelau (New Zealand); TON = Tonga; TUV = Tuvalu; VAN = Vanuatu; WAL = Wallis and Futuna (France). Note: Position of symbols is not representative of locations of take data.
The Pacific coast of Mexico accounts for the current greatest proportion of recorded illegal take with 47.8% (6644 turtles year⁻¹), followed by Indonesia (23.6%; 3279 turtles year⁻¹) and Fiji (23.4%; 3261 turtles year⁻¹) (see Table S1).

DISCUSSION

This study provides the first global synthesis of the reported legal direct take of marine turtles. Our estimate of current legal take, in excess of 42,000 turtles year⁻¹, highlights this as a potential threat to at least some marine turtle populations, but also places this threat in the context of others such as bycatch, that is likely to have a greater impact on global stocks. Our study also shows that there has been a 60% decrease in take from the countries within this study since the 1980s, with further decreases in the global take likely as many countries prohibited take during the period 1980–2010 (e.g. Cuba, Bahamas and Barbados) (Bräutigam & Eckert, 2006). Many green turtle populations, the most heavily targeted species, have also shown large increases in nesting populations in recent decades (Broderick et al., 2006; Chaloupka et al., 2008), potentially facilitated through the reduction or cessation in global take at these sites.

Bycatch estimates for marine turtles have been the focus of a number of relatively comprehensive studies in recent years. Wallace et al. (2010) estimated a minimum global bycatch of 85,000 turtles between 1990 and 2008 but suggest that this likely underestimates the true total by at least two orders of magnitude (due to < 1% fishing effort observed and recorded and underrepresentation of small-scale fisheries in bycatch data). For instance, more recent work by Casale (2011) estimated that there were 44,000 incidental sea turtles deaths year⁻¹ alone in the Mediterranean whilst Mancini et al. (2011) estimated that there were > 1000 deaths year⁻¹ within one fishery in a lagoon in NW Mexico. Small-scale fisheries in Peru capture tens of thousands of turtles as bycatch annually (Alfaro-Shigueto et al., 2011). These few estimates alone strongly suggest that global mortality from bycatch greatly exceeds that of legal take and likely extends into hundreds of thousands per annum. Improvements have been made in some areas, however, with comparative declines (~60%) in bycatch reported since 1990 in US fisheries (Finkbeiner et al., 2011).

Illegal fishing for turtles also continues to be a major cause of mortality, both in countries within this study and those where take is illegal (Bräutigam & Eckert, 2006; Maison et al., 2010; Lam et al., 2011). We estimate that a minimum of 65,000 turtles have been taken illegally from Mexico since 2000 (Koch et al., 2006; Peckham et al., 2008; Mancini et al., 2011), and in Nicaragua, there is documented take of species other than the permitted green turtles (Lagueux et al., 2003). The scale of global illegal take is likely to be severely underestimated due to the inherent difficulty in collecting data on such activity. However, a number of reports highlight widespread artisanal fisheries taking thousands of turtles per years.
The majority of current legal take is of green turtles, although past take of olive ridley turtles was significant, there has been a substantial decline in the legal take of both species since 1980s. There has also been a corresponding increase in national legislation during this time that focuses on protecting turtles during breeding seasons whilst allowing customary and traditional users to continue fishing, and is likely a reason for the decline in take over the past 30 years.

The majority of countries with legal turtle take is located in small island states in the Caribbean and Pacific (Melanesia, Polynesia and Micronesia). Turtle take in the Caribbean tends to be legislated through closed seasons, size restrictions by species, permits and gear restrictions (Richardson et al., 2006), whereas turtle take in the Pacific is characterized by high cultural significance with associated customs (Rudrud et al., 2007; Bell et al., 2010; Rudrud, 2010). Both regions report declines in take over the last 30 years (Eckert et al., 1992; Fleming, 2001), in some cases due to a lack of interest from younger generations (e.g. Belize: Bräutigam & Eckert, 2006; British Virgin Islands: S. Davies pers. comm.; Cook Islands: M. White pers. comm.; Samoa: J. Ward pers. comm.; Tokelau: F. Tulafono pers. comm).

However, the three largest legal fisheries persist in Papua New Guinea, in the waters of Australia and on the Atlantic coast of Nicaragua. Estimates used in this study for Nicaragua are, however, based on data from the 1990s, although current levels of take have decreased since last published estimates (C. Lagouve pers. comm.). There are also complications when estimating take for Papua New Guinea and Australia because the majority of turtle take is centred in remote areas of both countries. Furthermore, turtles are taken across the jurisdictions of Australia and Papua New Guinea by Australian Aboriginal and Torres Strait Islanders, as well as the coastal communities in Papua New Guinea and Indonesia. Estimates for the Torres Strait region (includes Torres Strait Islanders and neighbouring Papua New Guinea communities) in the past have been highly variable, from 5100 to 6700 (Kwan, 1991) to 10,000 per year (Limpus, 1980). This study estimates that the take from the whole of Papua New Guinea and Australia is in the order of 20,000 turtles per annum. However, there are limitations to these data from Australia due to the fact that they have been extrapolated from small data sets with restricted spatial and temporal limitations, and there are known large variations in numbers of nesting turtles each year (Limpus, 2008). Results of recent Australian Government supported community-based management programmes, and bilateral Australia and Papua New Guinea projects are also not yet available (Kennett & Kitchens, 2009; Australian Government, 2013).

Although the level of legal take is likely to be relatively low compared with the combined threats of bycatch and illegal take, the existence of a legal fishery has been suggested as providing cover for continued illegal take of turtles (Pritchard, 2003; Reuter & Allan, 2006). Direct take can be more targeted than other causes of marine turtle mortality, often focusing on nesting females (Catry et al., 2009; Marco et al., 2010), and although many countries within this study prohibit the take of nesting turtles, small numbers of adults can represent a large percentage of the nesting population (Limpus et al., 2006; Harris & George, 2008). The impact of direct take can be worsened if high levels of take coincide with the breeding season (Martin et al., 2005; Bell et al., 2007). The migratory nature of turtles also means that otherwise protected nesting populations can be heavily exploited in nearby countries, such as foraging adult females in Nicaragua from the largest green turtle rookery in Tortuguero, Costa Rica (Campbell, 2003).

There were several difficulties in assessing the status of legal take, most notably the lack of data across many countries and species. Few fisheries departments contacted had any official data available, and in one country contacted data collection had lapsed unnoticed for 3–4 years. A lack of national level monitoring programmes meant that many estimates were based on local studies by research institutions or NGOs, with temporally sporadic data collection (Broderick, 1998; Havea & MacKay, 2009), often generating conservative estimates (Godley et al., 2004). Within our study, original research data were used where possible although in certain instances national estimates by authors as part of reports (e.g. Kinch, 2002) or personal communications were used (e.g. Albania: M. White).

A decline in available papers, reports and official fisheries statistics on legal take in recent years led to an increase in the proportion of estimated data from the 1980s to present day. Many of the current legal turtle fisheries are at the subsistence level or part of small-scale fisheries, which can be difficult to monitor, especially in remote regions in island states (Nichols, 2003; Andrews et al., 2006). Further complications in data collection and analysis can arise in the ambiguity between definitions of direct, opportunistic or incidental take by fishers and researchers (Fuller et al., 1992; Godley et al., 2004). Small-scale and artisanal fishers will often take turtles opportunistically on fishing trips not specifically targeting turtles (Hoyle, 1994; Fleming, 2001; Petro et al., 2007; Alfaro-Shigueto et al., 2011). On top of this, fishing effort can range from specialized dedicated groups, to small numbers of occasional, turtle fishers (Godley et al., 2004), taking turtles both legally and illegally (Aiken et al., 2001; Bräutigam & Eckert, 2006).

Legislation within many countries examined is unclear, and even officials can be operating under false assumptions of the reality of the legislation (Bräutigam & Eckert, 2006). Multiple pieces of legislation within countries have been
passed without consulting prior texts for continuity (Bräutigam & Eckert, 2006) or taking into account local stakeholders (Vanuatu: F. Hickey pers. comm.), with frequent changes in restrictions (Caribbean Nicaragua: K. Garland pers. comm.). Many aspects of legislation associated with legal take can be difficult to monitor and enforce, such as restrictions on turtle size and gear types (Buden & Edward, 2001). Furthermore, legislation that allows for subsistence or traditional take can be hard to enforce due to difficulties in definitions; for example, the Nicaraguan green turtle fishery is defined as for subsistence use only but essentially runs at a commercial level (Campbell, 2003).

The debates on the continued legal take of marine turtles span a number of complex issues including ecological principles, human rights and animal welfare (Hamann et al., 2010), and still features in emotionally charged news articles (Holland, 2013). Undoubtedly, bans on large-scale turtle take have helped marine turtle populations to recover (Chaloupka et al., 2008), and current illegal take levels in some countries do not rival those of the previously legal turtle fishery (J. Chevalier in litt. in Bräutigam & Eckert, 2006) or current bycatch (Cornelius et al., 2007). Some countries in this study reported that legal take is declining further (Fiji: M. Raicebe pers. comm.; Cayman Islands: J. Blumenthal pers. comm.).

However, when considering current legal take it should be put in the context of the wider global threats to marine turtles, such as climate change and habitat degradation highlighted as conservation priorities by turtle researchers (Hamann et al., 2010). This study has shown that the relative impact of legal take on mortality could be less than the bycatch estimates from the Mediterranean alone (Casale, 2011). However, further assessments are warranted to understand where conservation priorities should be focussed due to the paucity of up-to-date data on direct take, and a lack of both direct take and bycatch information from small-scale fisheries.

Despite a loss of traditions, turtles remain culturally significant in many countries in this study (especially within Pacific islands), and it is the desire to protect this important cultural resource that has led to control measures on turtle take by governments and traditional authorities (Adams, 2003). Cultural strengthening can play a role in resource management, and the high status awarded to turtles can provide powerful incentives for conservation and management (Hickey & Johannes, 2002; Adams, 2003). Research has indicated that with appropriate management, even depleted populations could recover whilst maintaining a level of take (Chaloupka & Balazs, 2007); although defining what level is sustainable involves a greater knowledge of the threats and links between legal, illegal and bycatch mortality of targeted turtle populations (Hamann et al., 2010).

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REFERENCES


**SUPPORTING INFORMATION**

Additional Supporting Information may be found in the online version of this article:

Figure S1 Estimated past annual turtle take.

Figure S2 Estimated global breakdown by species.

Figure S3 Regional estimated global breakdown by species.

Figure S4 Top countries by species for current estimated annual take.

Table S1 Estimated current annual take by species.

Appendix S1 Supporting references.

**BIOSKETCHES**

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Author contributions: F.H., A.B. and B.G. conceived the ideas; F.H. collected and analysed the data and led the writing.

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