Global population delineations and conservation status for marine turtles: tools, methods, and guidance

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Introduction

As sea turtle biologists and conservationists, we are often asked some version of the same question: “So, how are the turtles doing?” Although it is a simple question that is typically seeking a simple answer, addressing it adequately requires an honest, unbiased, and thorough appraisal of sea turtle conservation status and research priorities, and how they vary.

For example, if you answered by describing the status of globally distributed sea turtle species, you could confidently say that none will go completely extinct anytime soon. If you focused your answer on green turtles in the North Atlantic (Restrepo et al., 2023) or East Pacific Oceans (Seminoff, 2023), or Kemp’s ridleys in the North Atlantic (Bevans et al., 2016), or olive ridleys in the northern Indian Ocean (Shanker et al, 2024), you could describe recovering populations approaching historical abundance in some places. On the other hand, if your answer described leatherbacks in the Pacific Ocean (Laúd OPO Network, 2020) or Wider Caribbean (Northwest Atlantic Leatherback Working Group, 2018), you would have cause for grave concern. Your answer might vary depending on whether you quote trends in abundance of nesting females, their nesting activities, or density estimates from at-sea surveys. Maybe you would answer with estimates of turtle mortality due to accidental interactions with fishing gear, or human consumption of eggs or meat, or the uncertain but looming effects of climate change or plastic pollution.

In short, how turtles are doing depends on where you look and what criteria you use. Sea turtle conservation status varies widely, within and among species, and within and among regions. Accurately assessing these diverse realities requires a clear understanding and description of what is being assessed and how. Doing so allows us to identify and communicate conservation and research priorities, which is critical when resources needed for sustained conservation efforts are stretched thin.

But it's not just the turtles who are complicated. The global diversity of sea turtle researchers and management mandates leads to wide variation in how we assess sea turtle status and what those assessments mean. Because we share sea turtles across geopolitical boundaries and human cultures, we need a shared language about sea turtles and their status to design and implement internationally compatible and culturally pluralistic conservation strategies.

In this chapter, we summarize some notable existing frameworks for 1) delineating sea turtle population units and 2) assessing their conservation status. We use terminology for these frameworks that has been established in the sea turtle research literature. We also propose some approaches that might be useful in nuancing assessments such that they are useful for management. Our goal is to emphasize the importance of clearly defining the appropriate spatial and temporal scales, intended purposes, and expected implications of conservation status assessments so that their results can be most informative for conservation priority-setting and implementation.

Delineating population units for assessment

Sea turtle population structure is quite complex. Most individual species are distributed across the world, but individuals of the same species can vary in body size, age to maturity, fecundity, and abundance trends depending on where in the world they live. Sea turtles meet life history demands by relying on different habitats in sea and coastal biomes that span geopolitical and ecological boundaries (Wallace et al., 2010; 2023). They live as long as humans, with individuals from several overlapping generations contributing to complicated and cryptic (to human observers) population dynamics, all of which occur in a context of multiple threats and fluctuating environmental conditions. This complexity–as well as the diverse approaches humans use to study turtles–means that there are many scales at which sea turtle status can be described (Table 1). Thus, when attempting to answer "how are the turtles doing?," it is essential to first define "which turtles" by coherently defining sea turtle assemblages.

The appropriate scale of assessment depends on the goals of the assessment and how it will inform conservation strategies, which makes the decision about what the 'appropriate scale' is crucial. Below, we describe in detail various types of assessments. For numerous taxonomic groups in which species' distributions are geographically limited (i.e., narrow-ranged or endemic), assessing the status of the species at a 'global' scale is most appropriate. The vast majority of the roughly 157,000 species assessed by the International Union for Conservation of Nature (IUCN) Red List (www.iucnredlist.org) fall into this category. But for widely distributed species like sea turtles, something more refined is needed to reflect within-species variation. However, nesting beach-scale assessments–while the main source of our observation and abundance data–are usually too fine-scale to adequately capture the complexities of sea turtle population dynamics and their varied drivers. Population scales, or units between the global species and nesting sites, are often the more biologically appropriate targets for conservation

(Wallace et al., 2010). Definition of biologically defined population units can also incorporate considerations of timescales, both for how populations are defined as well as how they are managed (i.e., evolutionarily divergence for long-term conservation goals *versus* differences at genetic markers reflecting short-term goals) (*sensu* Moritz, 1994). Regardless, the most appropriate population unit or scale should be defined based on specific management objectives targeting threats and other factors determined to be conservation priorities (Taylor & Dizon, 1999).

Why does defining the population unit of assessment matter?

Sea turtle population structure and dynamics are complex, and so are the options for defining units or scales of sea turtle populations. So why is it important to be clear about how 'population' is defined?

First, there is no universally consistent definition of 'population' across biological, conservation, or policy contexts; the term is often used interchangeably across demographic levels of species in other contexts. Therefore, it is essential to choose a population delineation framework and communicate its terminology and definitions clearly to avoid confusion in the interpretation of assessment results and implications.

Second, the population units selected for a conservation status assessment will become the targets for conservation or recovery goals around which management strategies are then tailored, including conservation actions, research priorities, and monitoring activities. Further, while some degree of conceptual similarities exists among evolutionarily significant units (ESUs), regional management units (RMUs), distinct population segments (DPSs), and IUCN subpopulations (see Wallace et al. 2010 and below), each term comes from different processes, can be interpreted differently, and thus can have distinct implications. It is therefore critical to clearly define and understand the population unit under assessment to correctly interpret and apply the assessment results.

Ultimately, determining and delineating the appropriate sea turtle population unit for assessment as well as the appropriate assessment framework will be driven by the relevant management objectives. In the following sections, we summarize existing frameworks for identifying population units of assessment.

Using genetics to define population units

Genetic markers–i.e. a DNA sequence at a particular location (locus) on the genome–are widely employed to differentiate sea turtle assemblages (Bowen & Karl, 2007; Moritz, 1994). However, the choice of markers and the analyses used to distinguish among them can vary depending on conservation goals (Komoroske et al., 2017; FitzSimmons et al., this manual). At the highest intraspecific level, phylogeographic, ecological, behavioral, and morphological variation can be used to identify ESUs (Moritz, 1994). These ESUs, as well as other population units described below, have evolved independently for a significant period or adapted to different environmental conditions, making them distinct evolutionary entities. They are recognized as having unique evolutionary heritages requiring protection to maintain evolutionary potential.

At a practical level, however, genetic variation is better characterized through management unit (MU) or ‘genetic stock’ delineations, which are defined by “significant divergence of allele frequencies at nuclear or mitochondrial loci, regardless of the phylogenetic distinctiveness of the alleles” (Moritz, 1994). Thus, MUs are appropriate for population monitoring and conservation needs on ecological or typical management plan timescales because they allow assessment of the connectivity between turtle nesting sites and foraging or migratory habitats. MU delineation using mitochondrial markers refer to genetically defined assemblages of nesting female turtles, also referred to as nesting rookeries, or genetic stocks, and can be linked demographically by common exposure to processes in shared habitats or through male-mediated gene flow (Bowen & Karl, 2007; Jensen et al., 2013; FitzSimmons et al., this manual; Shamblin et al., this manual). Novel approaches adding nuclear markers have improved resolution and understanding of population boundaries including the extent of male-mediated gene flow between populations not assayable using mitochondrial studies alone (Roden et al., 2023). Where genetic sampling and analyses are available, MUs can provide a useful basis for management frameworks and conservation prioritization, as represented in the national recovery plans that incorporate population genetics information as in the Recovery Plan for Marine Turtles in Australia (Department of the Environment and Energy, 2017), the Recovery Plan for Northwest Atlantic loggerheads (NMFS & USFWS, 2008), the biological review of green turtles (Seminoff et al., 2015), and the Mexican Action Plan for the Conservation of the Hawksbill turtle (SEMARNAT, 2020).

Genetically driven population delineation approaches continue to comprise a powerful and continually improving toolbox for sea turtle conservation prioritization (FitzSimmons et al., this manual). However, gaps in genetic sampling and analytical resources in some regions occasionally prevent consistent implementation of these approaches at the global scale (Shamblin et al., this manual). Thus, other frameworks, along with genetics, have been developed to provide globally applicable guidance for conservation assessments and priority-setting.

Regional Management Units

Sea turtle RMUs were developed in 2010 and updated in 2023 to provide a globally consistent, biologically derived framework for delineating conspecific assemblages above the level of breeding rookeries or individual MUs but below the level of species (Wallace et al., 2010; 2023). RMUs integrate various types of biogeographical information, including the locations of nesting sites, the genetic stocks to which they belong, geographic distributions at sea based on available monitoring data (e.g., sightings, mark-recapture), and movements, habitat use and distributions derived from satellite telemetry and tag returns. RMUs provide a flexible framework for characterizing sea turtle population complexity–from nesting sites to genetic stocks to shared marine habitats–for managers and researchers to use across a wide range of conservation objectives.

RMUs were first defined through an initial compilation and synthesis of available biogeographical information on all sea turtle species from around the world, which was then organized into spatially explicit polygons approximating distributions for each RMU. Nesting sites–organized into MUs where possible–were used as 'anchors' for these polygons, which expanded into marine areas based on available spatial data on turtle presence, movement, habitat use, and distribution. Global sea turtle experts then reviewed these draft RMU polygons during in-person workshops of the MTSG Burning Issues initiative (https://www.iucn-mtsg.org/burning-issues), and their input was instrumental in establishing the initial RMU boundaries (Wallace et al., 2010).

RMUs were recently updated using information made available since 2009 (>500 new sources) but via a more inclusive, extensive, and remote process (described in Wallace et al., 2023). Briefly, new map layers for published genetic stocks and digitized spatial data from published research were generated and provided to the global MTSG membership via an online ArcGIS platform for review and editing. The 48 updated RMU polygons (and genetic stock layers) created for all sea turtle species (except flatbacks, see Wallace et al. 2023) based on inputs from 49 MTSG members from around the world. From the original 56 RMUs defined for 6 species in 2010 (Wallace et al., 2010), 48 RMUs were defined in 2023, ranging from a single RMU for Kemp's ridleys to 13 RMUs for hawksbills (Wallace et al., 2023). In addition, the number of published mtDNA-defined MUs doubled from 87 stocks to 166 stocks across all 7 species, ranging from a single genetic stock for Kemp's ridleys to 73 green turtle stocks.

A key feature of RMUs is that they are spatially explicit; i.e., they have defined map boundaries based on empirical data and expert knowledge. Thus, RMU map boundaries provide a framework for evaluating threat impacts across the entire life history range (e.g., Fuentes et al., 2013; Senko et al., 2020; Senko & Burgher et al., 2022; Wallace et al., 2013a; 2020) to determine conservation status and priorities for sea turtle assemblages (e.g., Barrios-Garrido et al., 2020; Mazaris et al., 2014; Wallace et al., 2011) utilizing common geographic areas.

Other population delineation frameworks

Other population delineation approaches are outlined by official entities, including national legal frameworks. For example, the IUCN *Red List of Threatened Species*™ (www.iucnredlist.org) guidelines recognize official status of global species as well as "subpopulations" of species (IUCN, 2019). The IUCN defines a "subpopulation" for Red List purposes as a "geographically or otherwise distinct group in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less)" (IUCN, 2019) (Table 1). RMUs were developed, in part, to provide a basis for subpopulation level IUCN Red List assessments performed by the IUCN Marine Turtle Specialist Group (MTSG; www. iucn-mtsg.org) in an attempt to address long-standing conceptual and factual issues with global-scale sea turtle Red List assessments (Godfrey & Godley, 2008; Havice et al., 2018; Seminoff, 2004a; Seminoff & Shanker, 2008; Wallace et al., 2010). By the time of writing this chapter, Red List assessments have been performed for all subpopulations of leatherbacks, loggerheads, and most green turtles, using RMUs as the basis for subpopulation delineation. Notwithstanding the aforementioned problems with global-scale Red List assessments of sea turtle species, the IUCN accepts official subpopulation-level Red List assessments only if the global species has also been assessed (IUCN, 2019). Thus, the MTSG typically assesses subpopulations of a species first, which then inform an updated global assessment. However, following previous recommendations (e.g., Godfrey & Godley, 2008; Mrosovsky, 2003; Seminoff, 2004a; Seminoff & Shanker, 2008), the MTSG strongly encourages the use and communication of subpopulation-level Red List assessments instead of global-level assessments for conservation prioritization and other processes. Realistically, the primary value of global Red List assessments for sea turtles is to facilitate official recognition of subpopulation assessments by the IUCN.

Another population delineation framework, DPSs, is defined by the USA's Endangered Species Act of 1973 as "a vertebrate population or group of populations that is discrete from other populations of the species and significant in relation to the entire species" (ESA; 16 U.S.C. § 1531 *et seq.*; https://www.govinfo.gov/content/pkg/FR-1996-02-07/pdf/96-2639.pdf). ESA provides several guidelines for defining 'discreteness' and 'significance' in order to delineate DPSs (Table 1). As with the Red List, ESA allows DPSs as well as the global species to be included on the Endangered Species List. DPSs have been defined for purposes of ESA assessments for loggerheads (Conant et al. 2009) and green turtles (Seminoff et al., 2015). (NB: DPSs were defined for leatherbacks as well (NMFS & USFWS, 2020), but not officially because the ESA assessment for leatherbacks determined that the species listing of Endangered applied to the species globally, thus obviating the need to assess individual DPSs.) Further, similar to IUCN subpopulations, RMUs and DPSs are conceptually similar, as are the information types and processes for defining them. In fact, loggerhead DPSs and RMUs are nearly identical (see Wallace et al., 2010 for details). In addition, green turtle DPSs designated in 2015 provided the starting point for updating RMUs, which essentially confirmed the DPSs (see Wallace et al., 2023 for details).

Table 1. Examples of frameworks to delineate population scales for conservation status assessments. See text for more details on each.

Population scale	Information required	Life stages included	Spatially explicit?	Scale	Examples/References
Species	Distribution, genetic population structure, nesting sites	All	Typically	Global	Global-scale Red List assessments
Subpopulation	Distribution, tracking/movements, genetic population structure (e.g., ESUs, MUs, see below)	All	Typically	Regional	Subpopulation Red List assessments for leatherbacks, loggerheads, and green turtles
Regional management unit (RMU)	Distribution, tracking/movements, genetic population structure (MUs, see below), nesting locations	All	Yes	All scales included, but most appropriate below species, above genetic stock stock/nesting site level	Wallace et al., 2010; 2023
Distinct Population Segments (USA Endangered Species Act [ESA])	Distribution, tracking/movements, genetic population structure, nesting locations	All	Yes	All scales included, but most appropriate below species, above nesting stock/site level	USA Endangered Species Act; Seminoff et al., 2015
Evolutionarily Significant Units (ESUs)	Genetic population structure (i.e., distribution and phylogeny of mtDNA alleles and distribution of nDNA alleles), sampling locations (nesting or in-water sites)	All, but often nesting females	No	Site to regional	Moritz, 1994
Genetically defined Management Units (MUs) [,3]	Genetic population structure (i.e., allele frequencies), sampling locations (nesting or in-water sites)	All, but often nesting females	Yes, if specific nesting site(s)	Site to regional	Dutton et al., 2013; FitzSimmons & Limpus, 2014; Jensen et al., 2016; Moritz, 1994; Shamblin et al., 2014; Wallace et al., 2023
Nesting rookeries	Nesting locations, nesting beach monitoring	Nesting females, hatchlings	Yes	Local to sub-regional	State of the World's Sea Turtles (https://seamap.env.duke.edu/swot) TurtleNet: https://apps.information.qld.gov.au/TurtleDistribution/

[1]Discreteness: A population segment of a vertebrate species may be considered discrete if it is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors, or it is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or significant regulatory mechanisms.

[2] Significance: If a population segment is considered discrete under one or more of the above conditions, its biological and ecological significance will then be considered, including, but is not limited to, persistence of the discrete population segment in an ecological setting unusual or unique for the taxon; evidence that loss of the discrete population segment would result in a significant gap in the range of a taxon; evidence that the discrete population segment represents the only surviving natural occurrence of a taxon that may be more

abundant elsewhere as an introduced population outside its historic range, or; evidence that the discrete population segment differs markedly from other populations of the species in its genetic characteristics.
[3] Can include Demographically Independent Population (DIP) units where nDNA analysis reveals further fine-scale structure within a mtDNA based MU (see Dutton et al., 2013).

Assessing conservation status

Several assessment frameworks exist, which means there are several approaches available to answer the question of "how are the turtles doing?". For example, identifying species or populations that are at imminent risk of global extinction is quite different to characterizing population viability or trends in abundance. A population in decline relative to some past abundance estimate is not necessarily 'threatened with extinction.' Conservation priorities are typically not the same as research priorities. Thus, choosing the appropriate assessment framework, and understanding, interpreting, and communicating the results clearly are fundamental but often overlooked steps (Table 2).

We must first ask ourselves, "what is the purpose of this assessment?" And then, "what do the results mean for conservation strategies?" Assessment frameworks can result in some bold, one-word definitions of conservation status, such as those of IUCN Red List (e.g., "Critically Endangered," "Vulnerable"; IUCN, 2019) or several national-scale approaches (e.g., USA's Endangered Species Act: "Threatened" or "Endangered" [ESA; 16 U.S.C. § 1531 *et seq*.; https://www.fws.gov/law/endangered-species-act]; Canada's Species At Risk Act: "Extinct, "Extirpated," "Endangered," "Threatened," or "Special Concern" [S.C. 2002, c. 29; https://laws-lois.justice.gc.ca/eng/acts/S-15.3/]; or Mexico's NOM-059-SEMARNAT-2010: "Extinct", "Endangered", "Threatened"; "Subject to special protection"). They might assess vulnerability or resilience of sea turtles to potential climate change effects or some other threat (Lettrich et al., 2020). They might assess multiple criteria about sea turtle population risk and threats to describe the broad diversity in sea turtle conservation status (e.g., Wallace et al., 2011). They might apply population modeling to evaluate potential effectiveness of conservation measures (e.g., Crouse et al., 1987). Each of these (and other) approaches can be extremely relevant to sea turtle conservation and management, but they are not interchangeable, and they should not be used for purposes for which they are not intended (Possingham et al., 2002; Seminoff & Shanker, 2008). Because they intend to promote effective conservation, assessments must be deployed strategically and transparently.

Researchers must also remain aware of the manner in which their assessments or categorizations may be used by others, especially for implementation and policy. In many parts of the world, higher threat categories invariably mean restrictions on access to research which may constrain both basic monitoring of populations as well as any research that involves handling animals (because they species are 'Endangered'). At the same time, these higher threat categories may not actually mitigate the threats the populations face. Further, in some cases, status assessments may not be possible due to gaps in data required to evaluate status. Because lack of information can be a risk factor that hinders effective conservation, these cases should be prioritized for greater research to resolve data deficiencies.

Threatened species lists

The broad use of threatened species lists, especially the IUCN Red List, illustrates the importance of appropriate selection and application of assessment frameworks (Table 2). Threatened species lists are typically intended to identify species at some risk of extinction or otherwise negative status, which can then be the targets of conservation planning and action. However, these lists are frequently used for purposes for which they were not intended, and thus perform poorly, such as setting priorities for resource allocation and protected area design or to report on the status of biodiversity or ecosystems (Possingham et al., 2002).

The Red List, because it is so widely recognized as a source of information about species conservation status, is perhaps most frequently mis-applied or misinterpreted, even by those who perform Red List assessments (Mrosovsky, 2003; Seminoff & Shanker, 2008). To be clear, the Red List's sole function is to identify species (or subpopulations; see below) at imminent risk of global extinction, based largely on trends in nesting abundance. Despite its relatively narrow focus and function, the Red List is used by many different audiences to describe biodiversity status and trends and set conservation priorities at regional and national scales, something the IUCN itself describes on its website (https://www.iucnredlist.org/about/uses). Further, though it is constructed to enable globally applicable assessment of species across the spectrum of organismal taxonomy, it can generate misleading results and messaging for some species, particularly widely distributed, long-lived taxa like sea turtles (see Seminoff & Shanker, 2008 for review). For example, although it is implausible that any sea turtle species will go globally extinct any time soon, evaluating global status of sea turtle species against Red List criteria leads to results of threatened categories that may be unrealistic at some regional scales (e.g., Casale & Tucker, 2017; Seminoff, 2004b; Wallace et al., 2013b). Most sea turtle species do not have a real risk of extinction at a global scale, especially when compared to species that are truly range restricted or rare. This mismatch between Red List results and reality strains credibility and creates confusion (Godfrey & Godley, 2008; Mrosovsky, 1997). The numerous, serious technical and conceptual issues about the appropriateness of Red List criteria for evaluating sea turtle conservation status have been covered extensively elsewhere (e.g., Godfrey & Godley, 2008; Mrosovsky, 2003; Seminoff & Shanker, 2008; Webb, 2008).

In addition to these issues, conservation priority-setting tends to myopically focus on species that qualify for a threatened species list, a fact that can warp how we characterize and communicate conservation status. For example, if a sea turtle species or subpopulation is evaluated to be of "Least Concern" of imminent extinction in the wild according to Red List criteria–a status that says nothing about its dependence on conservation efforts nor whether serious threats exist–this actually becomes a source of great concern among people and entities working to reduce threats to turtles because resource-constrained decision-makers might wrongly interpret this label to mean that there is nothing to worry about. Similarly, in the USA, a species being 'downlisted'—i.e., removed from the Endangered Species List—typically causes consternation rather than celebration because of the potential loss of government-backed resources and enforcement of conservation actions to protect that species and its critical habitats (Doremus, 2000). This is especially true when there is no 'safety net' legislation in place (e.g., U.S. Marine Mammal Protection Act; European Union Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora) that affords protection regardless of official status.

To be clear, threatened species assessment frameworks can be quite effective in providing stakeholders and management authorities with clear opportunities for targeted conservation efforts, and, when connected to regulatory authority, can be effective tools for species recovery and habitat conservation. But understanding the purpose(s) for which these types of assessments were designed, as well as the types and quality of information used, and thus the proper extent of their application(s), is critical.

Assessing the full spectrum of conservation status

Conservation status varies widely among sea turtle populations according to population-specific biological traits and impacts of different threats, with environmental factors providing an overarching influence. Therefore, no 'one-size-fits-all' prioritization scheme will effectively respond to the wide variety of conservation and research needs across all populations. Instead, to reflect variation in conservation status and priorities, holistic status assessments should evaluate biological criteria (e.g., abundance, trends, and underlying demographic variables) and threats separately to understand drivers of overall status and thus targets for conservation interventions. This stepwise approach should accommodate local or regional nuances and thus provide managers, researchers, and local stakeholders with realistic conservation priorities. Partially in response to this need and the aforementioned challenges in assessment scales and interpretations, the IUCN MTSG—the entity responsible for undertaking Red List assessments of sea turtles—devised an assessment framework specific to sea turtles: the 'Conservation Priorities Portfolio' (CPP) (Wallace et al., 2011, 2025) (Table 2). This CPP framework is based on standardized criteria defined by sea turtle experts to evaluate population risk as well as population-level impacts of threats first separately, and then as complementary suites of relevant criteria (Fig. 1). The resulting portfolio provides a comprehensive view of status of all sea turtle regional management units (Wallace et al., 2010; 2023), globally, with no particular status results receiving *a priori* emphasis. The results from this assessment provided rich information on several criteria–as well as data needs–deemed important for sea turtle conservation at several relevant scales (Wallace et al., 2011, 2025) (Fig. 1). However, while this framework could theoretically be adapted for other species, it is, in its current form, only applicable to sea turtles, and has no regulatory or binding management impetus or application. These factors limit the uptake and utility of the CPP framework. This system was recently updated using information produced since the previous assessment, to include consideration of conservation capacity criteria (Wallace et al. 2025).

Other types of assessments

Beyond conservation status assessments, other frameworks exist to meet specific conservation or policy goals (Table 2). Detailed assessments of specific threats to sea turtles compile valuable information in attempts to evaluate the relative effects of threats on populations, or to call attention to the threatening phenomenon itself. Many of these are linked to regional or national management or recovery plans for particular species within that political geography. For example, in-depth assessments of relative impacts of various threats (scaled by reproductive values of life stages affected) informed development of recovery plans for the Northwest Atlantic loggerhead DPS (NMFS & USFWS, 2008), Kemp's ridley turtles (NMFS, USFWS &

SEMARNAT, 2011) in the United States, the Canadian Atlantic population of leatherback turtles (Fisheries and Oceans Canada, 2020), and hawksbills in México (SEMARNAT, 2020).

Inter-governmental instruments also implement assessments to meet their specific conservation goals and fulfill their convention charters. For example, the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC) requires that member parties (i.e., signatory countries) provide annual reports that describe 1) sea turtle nesting abundance and threats within their jurisdictions and 2) the status of actions implemented to comply with requirements of IAC's conservation resolutions. These annual reports are supposed to include actions taken by non-governmental organizations as well as government authorities and should provide sufficient detail to permit robust evaluation of compliance with binding resolutions designed to reduce threats and enhance protections for sea turtles. Thus, all relevant conservation actions and information collected can contribute to meeting a country's obligations as IAC signatories to sea turtle conservation. The information required to evaluate compliance with resolutions varies according to the resolutions, but include abundance monitoring data, threats assessments, creation of protected areas and other conservation policies, and the effectiveness of conservation measures to reduce threats impacts. For example, the IAC regularly assesses threats and nesting trends for loggerhead turtles across the 15 signatory nations (IAC, 2023), as mandated by the IAC "Resolution on the Conservation of the Loggerhead Sea Turtle (*Caretta caretta*)" (CIT-COP7-2015-R3). Further, the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA) created the Network of Sites of Importance for Marine Turtles in the Indian Ocean (https://www.cms.int/iosea-turtles/en/activities/site-network) to promote the long-term conservation of sites of regional and global importance to marine turtles and their habitats.

In contrast to these government-driven national and multi-national assessments, Senko et al. (2020) responded to growing interest among the marine conservation community as well as the general public and compiled available information about adverse effects of marine debris pollution–especially plastics–on marine megafauna species (e.g., seabirds, marine mammals, and sea turtles). Available information did not demonstrate evidence of population-level impacts of plastic pollution on any species. In contrast, assessments of climate change resilience (Fuentes et al. 2013), as well as impacts of incidental capture in fisheries or 'bycatch' (Wallace et al. 2013) and oil spills (Wallace et al. 2020) highlighted population-level variation in vulnerability to effects of threats, as well as in available information. Such assessments can provide the 'best available science' about threats to sea turtles, highlighting key conservation priorities as well critical data gaps.

Table 2. Example frameworks used to assess sea turtle conservation status and inform conservation strategies.

Assessment framework entity	Example(s)	Purpose	Criteria considered
Globally standardized, non-governmental	IUCN *Red List of Threatened Species*™ (https://www.iucnredlist.org/)	Identify species (or subpopulations) at imminent risk of global extinction. Lists species by threatened categories approximating a relative risk of extinction as determined by different criteria: Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened, Least Concern, or Data Deficient.	• Criterion A: "decline criterion", i.e., long-term population size reduction in past vs present abundance • Criterion B: Geographic range limitation in form of either extent of occurrence and/or area of occupancy and reduction or fragmentation Criterion C: Small population size and decline • Criterion D: Very small or restricted population • Criterion E: Quantitative analysis indicating a certain probability of extinction in the wild within a given timeframe
National-scale, governmental	USA Endangered Species Act (https://www.fws.gov/law/endangered-species-act) Mexico Programa de Acción para la Conservación de las Especies (https://www.gob.mx/conanp/acciones-y-programas/programas-de-accion-para-la-conservacion-de-especies-pace-123484)	Establish protections for fish, wildlife, and plants that are listed as threatened or endangered[1] and implement plans for their recovery.	• The present or threatened, destruction, modification, or curtailment of its habitat or range; • Overutilization for commercial, recreational, scientific, or educational purposes; • Disease or predation; • The inadequacy of existing regulatory mechanisms; and • Other natural or manmade factors affecting its continued existence
Intergovernmental bodies, general	• Convention for the International Trade of Endangered Species (CITES; https://cites.org/) • Convention for Migratory Species (CMS; https://www.cms.int/)	• CITES: Ensure that international trade in plants and animals does not threaten their survival in the wild. All marine turtle species are Appendix 1 (prohibits international trade) • CMS: Provides a global platform for the conservation and sustainable use of migratory animals and their habitats by bringing together the States through which migratory animals pass, the Range States, and lays the legal foundation for internationally coordinated conservation measures throughout a migratory range. Flatback turtles (*Natator depressus*) is Appendix II, while all other marine turtle species are Appendix 1.	• CITES: The species covered by CITES are listed in three Appendices, according to the degree of protection they need. Appendix I includes species threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances. Appendix II includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival. Appendix III contains species that are protected in at least one country, which has asked other CITES Parties for assistance in controlling the trade. • CMS: Appendix I comprises migratory species that have been assessed as being in danger of extinction throughout all or a significant portion of their range. Appendix II covers migratory species that have an unfavorable conservation status and that require international agreements for their conservation and management, as well as those that have a conservation status which would significantly benefit from the international cooperation that could be achieved by an international agreement.

Assessment framework entity	**Example(s)**	**Purpose**	**Criteria considered**
Intergovernmental bodies, sea turtle-specific	• Indian Ocean-Southeast Asia Sea Turtle Memorandum of Understanding (IOSEA; https://www.cms.int/iosea-turtles/) • Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC; http://www.iacseaturtle.org/)	• Identify regional nesting trends for priority species • Identify sites of importance and conservation priorities • Evaluate degree of compliance with implementation of conservation resolutions by of member countries	Criteria defined by individual resolutions and agreements, typically focused on actions taken by member countries to reduce identified threats
IUCN Marine Turtle Specialist Group	Conservation Priorities Portfolio (Wallace et al., 2011, 2025)	Generate a 'portfolio' of sea turtle conservation status and priorities using regional management units as the basis of assessment by evaluating current status of criteria describing population risk or viability, threats impacts, and conservation capacity	• Risk or population viability (e.g., abundance, short-and long-term trends, rookery vulnerability, genetic diversity) • Population-level impacts of threats (e.g., bycatch, direct take, coastal development, pollution, climate change) • Conservation capacity (e.g., socio-economic status, enforcement capacity, resource availability, technical expertise/knowledge, coordination capacity)
Threats assessments by researchers or management authorities	• Climate change (e.g, Fuentes et al., 2013; Lettich et al., 2020) • Bycatch impacts (e.g., Wallace et al., 2013) • Direct take (e.g., Humber et al., 2014; Senko & Burgher et al., 2022) • Marine debris (e.g., Schuyler et al., 2016; Senko et al., 2020) • USA ESA recovery plans (e.g., NMFS & USFWS, 2008)	• Quantify estimated sea turtle mortality caused by an anthropogenic threat • Evaluate the relative population-level impact of a threat or threats • Identify data gaps	• Quantification of mortality (number of individuals), by species, population, and life stage • Population-level impacts of threats, e.g., via reproductive value • Types and quality of available information to evaluate threats impacts

[1] "Endangered" = "any species which is in danger of extinction throughout all or a significant portion of its range." "Threatened" = "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

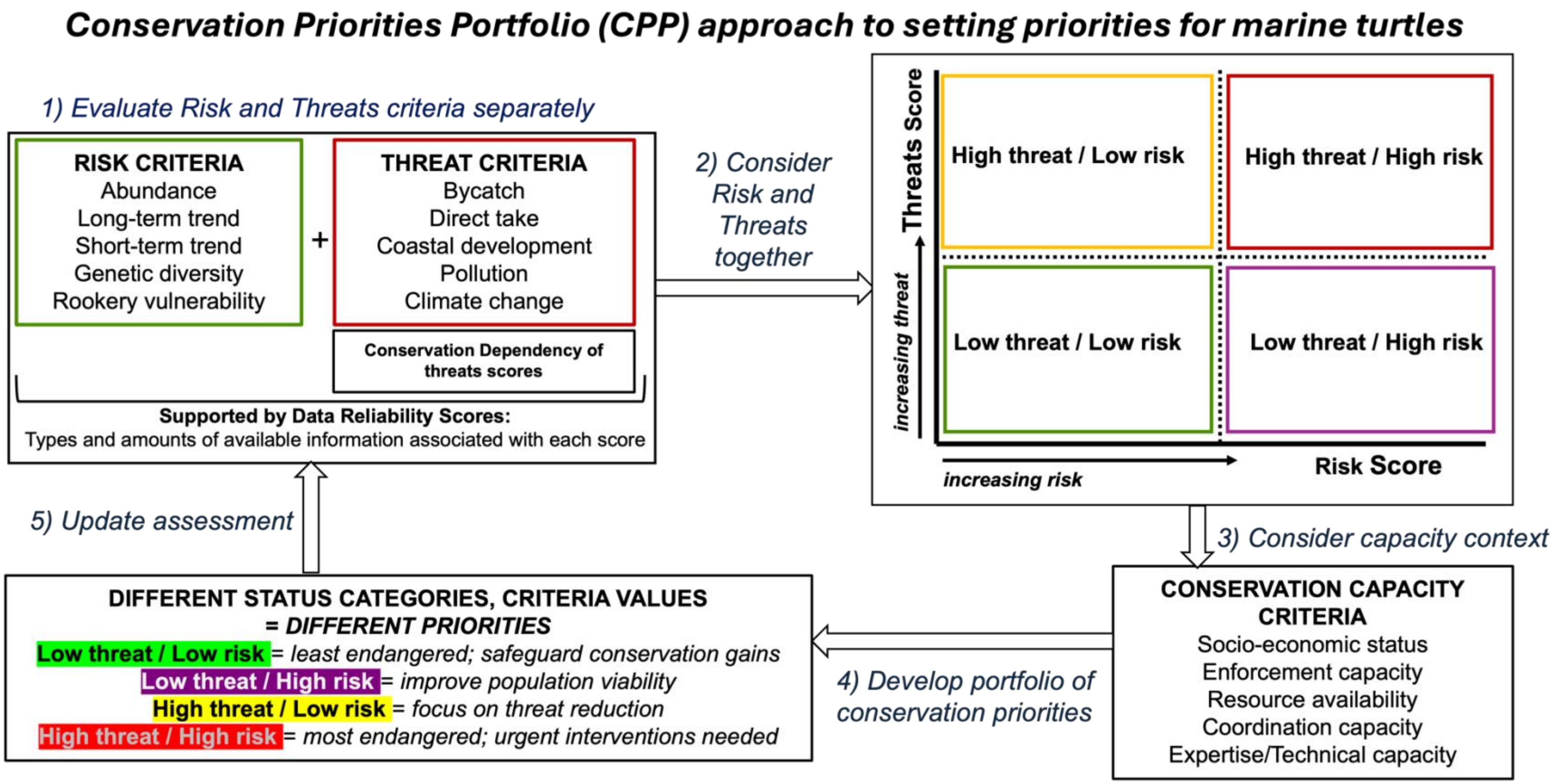

Figure 1. Process (steps numbered and in blue font) for holistic status assessments that consider biological (demographic risk or viability) criteria and threats impacts–as well as conservation capacity criteria–to generate a 'portfolio' of conservation priorities for sea turtles. This process allows identification of individual criteria as well as characterization of general status categories that warrant development of targeted conservation efforts to address 'population'-specific priorities.

Getting the most out of our data

The examples described above highlight the importance of identifying numerous and diverse applications of data and knowledge generated in monitoring and conservation programs. Many types of information are valuable in multiple contexts and applications for sea turtle conservation priority-setting and planning, beyond the specific purpose initially envisioned for such information. However, we must be transparent about limitations to the availability and robustness of available data when using them in assessments with implications for sea turtle conservation and policy initiatives, as well as about limitations for any given assessment that uses these data to describe conservation status. Further, transparency should extend to drawing conclusions about status based on available information and how it was interpreted according to the assessment criteria and process. Being honest about what we do know *versus* what we do not will enhance credibility and improve the likelihood of our information successfully informing effective conservation actions.

Beware unintended consequences

Understanding the intended purposes and applications of assessments is essential, but being aware of and trying to avoid unintended consequences and their implications is also the responsibility of anyone undertaking a conservation status assessment. Many conservation status assessment frameworks tend to perpetuate tenets and values of Euro-centric science and conservation, which can exclude local perspectives about status and conservation priorities (Shanker et al., 2022; 2023). Global conservation assessments can severely hamper local research by constraining access, but more importantly, they can impact the lives and livelihoods of marginal communities. This raises serious questions about the ethics of these assessments and consequences for social and environmental justice.

For example, we need to identify who or what entity designed the framework and for what purpose, what types of information are required and who or what entity has it, and who or what entity through what process will make decisions based on the assessment results. Whomever is not included in the design and intended applications are those who could be negatively affected. When we perform assessments, it is critical that we identify all relevant stakeholders and audiences of conservation status assessments, especially if their perspectives and priorities are not explicitly incorporated.

Conclusions and Recommendations

As described above and elsewhere, there are several ways to delineate sea turtle population units, and many ways to assess the conservation status and identify priorities for those population units. Finally, we provide some considerations for delineating and assessing sea turtle population units.

- Ultimately, selection of the appropriate approach(es) should be driven by the management or conservation need, identified by stakeholders, legal instruments, or some other established priority.
- Regardless of the framework, results and implications of status assessments should be connected to the unit of assessment, and not necessarily up- or down-scaled to another

population unit. For example, conservation status of individual genetic stocks might not be sufficient to characterize the impacts of threats or overall status at the scale of RMUs or ESUs, or *vice versa*.

- Conservation priorities are typically not the same as research priorities. Thus, it is critical to choose the appropriate assessment framework, and to properly understand and interpret the results of a priority-setting exercise in the relevant context.
- Maintain transparency and awareness of data limitations, as well as the downstream interpretation and implications of assessment results to ensure that they are applied appropriately and effectively, and avoid unintended consequences and extrapolation beyond intended applications.
- Units of assessment and how they are defined are not static entities or processes. As such, they should be updated at intervals reasonable for turtle population dynamics (perhaps every 10 years or so) to maintain relevance and effectiveness of resulting conservation prioritization efforts. Whenever population delineations are used for assessments or research, how current these delineations are should be clearly noted to ensure accuracy.

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