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Status of the world's baleen whales

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Abstract

No global synthesis of the status of baleen whales has been published since the 2008 IUCN Red List assessments. Many populations remain at low numbers from historical commercial whaling, which had ceased for all but a few by 1989. Fishing gear entanglement and ship strikes are the most severe current threats. The acute and long-term effects of anthropogenic noise and the cumulative effects of multiple stressors are of concern but poorly understood. The looming consequences of climate change and ocean acidification remain difficult to characterize. North Atlantic and North Pacific right whales are among the species listed as Endangered. Southern right, bowhead, and gray whales have been assessed as Least Concern but some subpopulations of these species - western North Pacific gray whales, Chile-Peru right whales, and Svalbard/Barents Sea and Sea of Okhotsk bowhead whales - remain at low levels and are either Endangered or Critically Endangered. Eastern North Pacific blue whales have reportedly recovered, but Antarctic blue whales remain at about 1% of pre-exploitation levels. Small isolated subspecies or subpopulations, such as northern Indian Ocean blue whales, Arabian Sea humpback whales, and Mediterranean Sea fin whales are threatened while most subpopulations of sei, Bryde's, and Omura's whales are inadequately monitored and difficult to assess.

Key words: status, cetaceans, baleen whales, blue whales, whaling, ship strike, entanglement, bycatch, anthropogenic noise, climate change, ocean acidification, endangered species, IUCN, Red List.

Baleen whales (Mysticeti, or mysticetes) and their ocean habitat (Gattuso *et al.* 2015) are under stress throughout the world, yet there has been no up-to-date synthesis on the status[2] of this group since Clapham *et al.* (1999). Baleen whales have acquired iconic status in the conservation discourse, for their "charisma" (size, appearance, behavior, *etc.*), their global distribution, and especially the fact that sev-

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[2]Here status is considered to mean the degree to which a species or population is at risk of extinction. In other contexts status may refer to the size or general health of a population relative to some management standard (Barlow and Reeves 2009).

eral of the species and populations were nearly extirpated by commercial whaling, which continued on a massive scale until the early 1970s. It is generally assumed by nonspecialists that all whales are endangered. Actually, the level of endangerment of different species and populations is quite variable. The identification of species, subspecies, and subpopulations[3] (or what are often called "stocks" of whales within the Scientific Committee of the International Whaling Commission [IWC]; Allen 1980, Donovan 1991) is itself a major scientific task. Once the "units of conservation concern" (Taylor 2005) have been identified, the next scientific imperative is to determine their status. Key indicators of status are population size (abundance), rates of removals, and rates of population growth or decline. As part of analyses to determine status, consideration is given to the nature and severity of threats, which can apply at either the individual or population level. In considering anthropogenic factors that cause harm of some kind, from temporary disturbance all the way to death, managers have to evaluate whether the impacts on individuals are sufficient, in the aggregate, to affect parameters of the population as a whole, *e.g.*, birth rate, survival rates, recruitment rate, longevity).

In this paper we provide the first synthesis on the status of the world's baleen whales and the threats they face since Clapham *et al*. (1999).

Methods

We used as a starting point the assessment information provided for the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species (Red List) on the status of, and the threats faced by, all baleen whale species as well as some subspecies and subpopulations. The documentation behind the 2008 Red List assessments, in most instances coming from a 2007 workshop of the IUCN Species Survival Commission's Cetacean Specialist Group, is available on the Red List website (http://redlist.org).[4]

A major underpinning of the Red List assessments and of this current synthesis is the work of the IWC's Scientific Committee.[5] In addition to reviewing much of the primary literature cited in the Red List analyses, we conducted an in-depth review of IWC reports and publications, as well as of new literature available (through May 2015), with the goal of producing a comprehensive, up-to-date synthesis of what is presently known about the status of baleen whales and the conservation threats to individual populations. Sometimes the IUCN assessments are more recent or detailed than the IWC assessments and *vice versa*. Therefore the terminology (subpopulation or stock) we use may vary as we reflect the most current information. Also, it is

[3]In the present context, the term "subpopulation" follows Red List usage to mean a geographically or otherwise distinct group with little demographic or genetic exchange with other groups (typically one successful migrant individual per year or less) (IUCN 2012).

[4]The Red List documentation is cited herein following Red List convention, *i.e.*, under the authorship of the assessor(s) (Reilly *et al*. in most cases; Stephen Reilly chaired the working group dealing with baleen whales at the La Jolla, California, workshop) and with the "publication" year given in most cases as 2008 (according to the citation as recommended on the relevant page of the Red List website).

[5]The International Convention for the Regulation of Whaling exists for the explicit purpose of managing the exploitation and assuring the conservation of whales, including all of the baleen whales, most of which have been subjected to prolonged commercial whaling. The Scientific Committee is expected to provide authoritative advice on the status of whale stocks which is then used by the Commission in making management decisions.

important to note that for some species, *e.g.*, blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), and sei whales (*Balaenoptera borealis*), the IUCN Red List classification of Endangered is misleading because the global, range-wide assessments were dominated by the massive removals by historical commercial whaling, mainly in the Southern Hemisphere. Not all regional populations of those species are endangered. Where new information was available on taxonomy (through May 2015), we updated the Red List documentation in that respect (generally following the Society for Marine Mammalogy's Committee on Taxonomy (cited herein as Committee on Taxonomy 2015; see http://www.marinemammalscience.org).

The currently recognized species of baleen whales are the blue whale, fin whale, humpback whale (*Megaptera novaeangliae*), sei whale, Bryde's whale (*Balaenoptera edeni*), Omura's whale (*Balaenoptera omurai*), common minke whale (*Balaenoptera acutorostrata*), Antarctic minke whale (*Balaenoptera bonaerensis*), bowhead whale (*Balaena mysticetus*), North Atlantic right whale (*Eubalaena glacialis*), North Pacific right whale (*Eubalaena japonica*), southern right whale (*Eubalaena australis*), pygmy right whale (*Caperea marginata*), and gray whale (*Eschrichtius robustus*). In addition, the currently recognized subspecies of baleen whales are the North Atlantic minke whale (*B. acutorostrata acutorostrata*), North Pacific minke whale (*B. a. scammoni*), dwarf minke whale (*B. a.* unnamed subsp.), northern sei whale (*B. borealis borealis*), southern sei whale (*B. b. schlegellii*), offshore Bryde's whale (*B. edeni brydei*), Eden's whale (*B. e. edeni*), northern blue whale (*B. musculus musculus*), Antarctic blue whale (*B. m. intermedia*), northern Indian Ocean blue whale (*B. m. indica*), pygmy blue whale (*B. m. brevicauda*), Chilean blue whale (*B. m.* unnamed subsp.), pygmy fin whale (*B. physalus patachonica*), northern fin whale (*B. p. physalus*), southern fin whale (*B. p. quoyi*), southern humpback whale (*M. novaeangliae australis*), North Pacific humpback whale (*M. n. kuzira*), and North Atlantic humpback whale (*M. n. novaeangliae*).

Threats

Clapham *et al.* (1999) provided an overall review of the threats to baleen whales. They identified bycatch (entanglement or entrapment in fishing gear) and ship strikes as the primary threats at the population level and concluded that those threats were most significant for populations already at critically low numbers. We found that 15 yr later, these same threats remain among the most serious. In addition, commercial whaling in the form of research whaling or whaling under objection to the commercial whaling moratorium continues by Japan, Norway, and Iceland. An updated review of threats to baleen whales must consider, in addition to those identified by Clapham *et al.* (1999) (entanglement/entrapment, ship strike, whaling, pollution, disease, habitat degradation from oil spills), the cumulative impacts of anthropogenic noise and other stressors and the short- and long-term effects of climate change and ocean acidification on marine ecosystems.

Acute or Lethal Threats

Whaling has an immediate effect on populations through the direct removal of individuals. Two other threats—mortality in fishing gear and ship strikes—result in the deaths of individuals and their outright, immediate loss to the population. Indeed, the IWC Scientific Committee's Working Group on Estimation of Bycatch and other Human-induced Mortality recognizes this equivalence: the group's remit is to estimate these removals "so that such mortality can be subtracted from any catch limits that might be calculated using the RMP [Revised Management Procedure]" (IWC 2012*b*:221). Despite uncertainties as to their causes, we also include discussion of unusual mortality events in this section because of their possible consequences for populations.

Historical and Current Whaling

Whaling has been a major threat to most baleen whale populations in the past, and the legacy of commercial exploitation remains as a prominent force in determining their current status. Many populations are showing signs of recovery; others remain depleted; some are at very low numbers and may be vulnerable to extirpation by stochastic processes or catastrophic events (Clapham *et al.* 1999).

North Atlantic right whales and Svalbard/Barents Sea bowhead whales remain endangered from whaling that ceased a century or more ago, but several other depleted populations were the target of illegal Soviet whaling as recently as the 1970s (Ivashchenko and Clapham 2014). Significant information continues to be brought to light and published on the scale of Soviet illegal hunts in the Arabian Sea (Mikhalev 1996, 1997, 2000), South Atlantic (Tormosov *et al.* 1998), Antarctic (Yablokov 1994, Zemsky and Sazhinov 1994, Clapham and Ivashchenko 2009, Ivashchenko *et al.* 2011), and North Pacific (Brownell *et al.* 2001; Ivashchenko and Clapham 2012; Ivashchenko *et al*. 2013, 2014), which reduced populations of southern right whales, humpback whales, pygmy blue whales (*B. m. brevicauda*), North Pacific right whales, and Sea of Okhotsk bowhead whales as well as sperm whales (*Physeter macrocephalus*) in many parts of the world's oceans.

Although ongoing whaling (commercial whaling by Norway and Iceland under an objection to the moratorium and "research" or "scientific" whaling by Japan and Iceland) is a subject of controversy and public debate, it is not an *active* threat to most baleen whale species and subspecies (Clapham *et al.* 1999). Current levels of take in most of these hunts are near or below levels determined to be sustainable under the IWC's Revised Management Procedure (RMP) or by Iceland and Norway on the basis of similar algorithms. An exception is the taking of J-stock common minke whales by Japanese research whaling, bycatch in fishing gear in Japan and the Republic of Korea (Korea), and some illegal whaling by Korea (Song *et al.* 2010, MacMillan and Han 2011). Also, the sei whales in the North Pacific subject to research whaling have not recently been assessed (both in terms of numbers and population structure) by the IWC. The levels of noncommercial ("aboriginal subsistence") whaling (Reeves 2002) on gray whales in Russia, bowhead whales in Russia and the United States, bowhead, humpback, fin, and common minke whales in Greenland (Denmark), and humpback whales in St. Vincent and the Grenadines are based on IWC assessments and are generally considered sustainable (IWC 2012*a*, http://iwc.int/aboriginal).

Entanglement/entrapment in Fishing Gear

Incidental mortality (as well as morbidity) in fishing gear (hereafter "bycatch") is a ubiquitous problem for cetaceans in coastal and continental shelf waters and to a lesser extent in offshore areas (Read *et al.* 2006, Reeves *et al.* 2013). In some cases, bycatch has species- or population-level impacts. Gill net and trap/pot fisheries that use vertical lines to mark gear are responsible for much of the baleen whale bycatch (Reeves *et al.* 2013) although large-mesh shark control nets are a particular problem in South Africa and Australia (Meÿer *et al.* 2011). The susceptibility of species differs according to their size or habits and to the types of fishing gear used within their range. Bycatch has known population-level consequences for North Atlantic right whales (Johnson *et al.* 2007, Knowlton *et al.* 2012) and the western North Pacific subpopulation of gray whales (Weller *et al.* 2002, 2008) and it has been inferred to be the primary threat to the Arabian Sea subpopulation of humpback whales (Minton *et al.* 2011). Other baleen whale populations potentially threatened by bycatch, but for which data are very limited, include North Pacific right whales and the southeastern Pacific (Chile-Peru) subpopulation of southern right whales. Humpback whales are frequently entangled in fishing gear in the North Pacific and North Atlantic but U.S. stock assessments indicate that mortality levels from such entanglement are not high enough to threaten the humpback whale populations in U.S. EEZ waters, *i.e.*, they are below the potential biological removal or PBR level (Allen and Angliss 2011, Waring *et al.* 2011).[6] Because of their small size, nearshore and continental shelf distribution, and fish diet, minke whales are especially vulnerable to gillnet entanglement (Reeves *et al.* 2013).

Ship Strike

The threat of ship strikes is certain to increase as commercial ship traffic increases around the world (Clapham *et al.* 1999, Laist *et al.* 2001, Jensen and Silber 2003, McKenna *et al.* 2012*a*, Redfern *et al.* 2013, Monnahan *et al.* 2014*b*). Recently, Tournadre (2014) has shown that commercial ship traffic increased by a factor of four between 1992 and 2012 with maximums in the Indian Ocean and China seas. Ship strikes are of particular concern where the ranges (*e.g.*, feeding areas, calving areas, migratory routes) of threatened populations overlap with major shipping routes, entrances to major ports, or other areas of intense vessel traffic such as offshore industrial sites or high-speed ferry routes (Clapham *et al.* 1999, Kraus *et al.* 2005, Corbett and Winebrake 2007, Neilson *et al.* 2012).

The best-documented example of ship strikes having a significant impact on a baleen whale species is the North Atlantic right whale. In spite of measures to reduce the incidence of ship strikes along the east coasts of both Canada and the United States (Knowlton and Brown 2007), the average reported mortality and serious injury of right whales due to ship strikes from 2005 through 2009 was 1.6 whales per year —double the PBR level (Waring *et al.* 2011). In 2003 the traffic separation scheme in the lower Bay of Fundy (Canada) was modified to avoid an area with recurrent large concentrations of right whales in summer and fall (Knowlton and Brown 2007) and in 2006 the International Maritime Organization also approved a modification of the shipping lanes into Boston harbor to avoid an area of right whale concentration on Stellwagen Bank (Marine Mammal Commission [MMC] 2006). In December 2008 the U.S. National Marine Fisheries Service implemented a 5 yr rule requiring that within areas where North Atlantic right whales are likely to occur, large ships restrict their speed to 10 knots (MMC 2010) and preliminary analyses indicated it was effective (Laist *et al.* 2014). The rule was extended indefinitely in 2013.

The risk of ship strikes is affected by economic and climatic conditions (Corbett and Winebrake 2007, McKenna *et al.* 2012b). For example, it is expected that the dramatic, ongoing decline of sea ice in the Arctic will lead to more ship traffic in areas

[6]Potential biological removal (PBR) is the product of minimum population size, one-half the maximum net productivity rate, and a "recovery" factor ranging from 0.1 to 1 (MMPA Sec. 3. 16 U.S.C. 1362; Wade and Angliss 1997).

currently used intensively by baleen whales. Of particular concern are shipping and migratory chokepoints such as the Bering Strait, which connects the Bering and Chukchi seas (Reeves *et al.* 2012), and Unimak Pass, Alaska, and other straits through the Aleutian Islands used by both ships and whales to move from the North Pacific into and out of the Bering Sea.

Following a spate of fatal ship strikes on blue whales in the eastern North Pacific in 2007, voluntary measures were put in place to reduce the ship strike risk in California waters, especially the Santa Barbara Channel, an area of heavy traffic for Los Angeles and Long Beach harbors and seasonally high blue whale density, and off the port of San Francisco (Carretta *et al.* 2013, Redfern *et al.* 2013). McKenna *et al.* (2012*a*) found little compliance with voluntary speed-reduction measures in the Santa Barbara Channel, suggesting the need for alternative context-specific strategies to achieve speed reductions. However, Monnahan *et al.* (2014*b*) concluded that ship strikes have not had population-level effects on blue whales in the eastern North Pacific. Other subspecies and subpopulations known or suspected to be affected by ship strikes include pygmy blue whales, which frequent the busy shipping lanes off the southern coast of Sri Lanka (IWC 2012*b*), and Arabian Sea humpback whales, which are also exposed to intensive ship traffic in parts of their range. In neither case, however, has mortality been monitored sufficiently to assess the severity of the ship strike threat.

Health

Large-scale mortality events involving baleen whales are rare (Gulland and Hall 2007, Coughran *et al.* 2013, Rowntree *et al*. 2013). Biotoxins were implicated in two large events off New England in 1987 and 2003. The first involved 14 humpback whales that died in Cape Cod Bay after eating Atlantic mackerel (*Scomber scombrus*) containing saxitoxin, a dinoflagellate neurotoxin responsible for paralytic shellfish poisoning in humans (Geraci *et al.* 1989). The second, in Maine, involved the deaths of 16 humpback whales, one fin whale, one common minke whale, one pilot whale (*Globicephala* sp.), and two whales unidentified to species. While the cause of this second event was not determined, two kinds of biotoxin—saxitoxin and domoic acid—were detected in a few of the humpback whales examined (Gulland and Hall 2007). A large die-off of cetaceans of unknown cause was recorded in 1995 in the upper Gulf of California, Mexico. This event included hundreds of long-beaked common dolphins, *Delphinus capensis*, and at least eight baleen whales of three species (Vidal 1996). Forty-six humpback whales, 44% of them calves of the year, stranded on Western Australia beaches in 2009. While many animals appeared to be underweight, it proved impossible to determine cause of death (Coughran *et al.* 2013). Thirteen humpback whales stranded on Brazilian beaches in 2010 (Moura *et al.* 2012).

Starvation was considered a possible cause of a widespread gray whale die-off in 1999–2001, in which at least 651 deaths were confirmed, not all of which could be linked directly to poor body condition or starvation. The proximate cause of death differed for the few animals conclusively necropsied and it was hypothesized that parasite infestations, biotoxins, or infections finally killed animals that had been made vulnerable by malnutrition (Gulland *et al.* 2005). This event added substance to the ongoing discussion of whether eastern Pacific gray whales had reached or exceeded the environmental carrying capacity and it more generally prompted analyses of how environmental variability affects baleen whale life history and mortality patterns (Moore *et al.* 2001, Perryman *et al.* 2002).

Some of the best tools and baseline health information on baleen whales have come from studies of North Atlantic right whales (Rolland *et al.* 2007, 2012). Analyses of fecal samples have permitted evaluation of stress hormone levels (see below). Such analyses also confirmed the presence of biotoxins and potentially harmful parasites such as *Giardia* and *Cryptosporidium* in live right whales, yet none of these, or other disease processes, were determined to be the primary cause of death for any of the 39 North Atlantic right whales necropsied between 1975 and 2005. These whales died from blunt or sharp trauma from vessel strikes (n = 19), fishing gear entanglement (n = 5), or undetermined causes including neonatal complications (n = 15) (Moore *et al.* 2007).

Photo-identification research on some baleen whale populations has led to investigations of skin lesions (Hamilton and Marx 2005, Brownell *et al.* 2007, Van Bressem *et al.* 2014). An analysis of two types of lesions (white and blister) on North Atlantic right whales found that these were sublethal conditions that might somehow impact or reflect overall health. Large "swath lesions" (which are white) were found to be correlated with entanglement, thin body condition, and known or suspected mortality of most of the affected whales (Hamilton and Marx 2005). There was some evidence, although not conclusive, that white lesions are the result of a contagious agent. Fifty-two of 68 individual blue whales observed off Isla Grande de Chiloe, Chile, had raised or blister-like skin lesions and at least one whale had extensive tattoo-like lesions (Brownell *et al*. 2007).

Since 2003, southern right whales, mostly calves, have been dying in unusually large numbers in the calving/nursery grounds around Península Valdés, Argentina (Uhart *et al.* 2008, 2009; Rowntree *et al.* 2013). So far the cause(s) of these deaths has not been determined, but three hypotheses have been put forward to explain the die-off (IWC 2011). The mortality of calves may be a consequence of: (1) the poor nutritional state of the mothers; (2) exposure to algal or bacterial biotoxins in (a) the feeding ground resulting in *in utero* exposure of the calf or (b) in the calving/nursery ground; and (3) infectious disease (viral, bacterial, protozoal, *etc*.). More recently, attention has focused on a fourth possibility: that repeated attacks on calves by kelp gulls (*Larus dominicanus*) are leading to stress, dehydration, and shock as a result of gaping peck wounds (Rowntree *et al.* 2013, Thomas *et al.* 2013). Other factors such as contaminants, predation by killer whales (*Orcinus orca*), disturbance from whale watching, fishery interactions, and ship strikes were ruled out or judged to be unlikely major contributors to these die-offs (IWC 2011).

Sublethal or Chronic Threats

Disturbance from Human Activities

It has long been recognized that baleen whales, like other wild animals, can be disturbed by certain kinds of human activity. Because of their reliance on sound as a primary sensory modality, noise-generating activities are of particular concern (Richardson *et al.* 1995, Nowacek *et al.* 2007, Southall *et al.* 2007, Moore *et al.* 2012*a*). Beginning in the 1970s, scientists drew the attention of management agencies to the risks posed by underwater noise to small, recovering populations of baleen whales. For example, salt barge traffic was believed responsible for preventing gray whales from using Guerrero Negro Lagoon in Baja California, Mexico, for a period during the 1950s and 1960s (Gard 1974), and there was much discussion of the possibility that "harassment" by whale-watching boats was jeopardizing recovery of eastern Pacific gray whales (Reeves 1977). Similar concerns were expressed regarding humpback whales in Hawaii (Norris and Reeves 1978, but also see Tyack 1989). Offshore oil and gas exploration in the U.S. and Canadian Arctic, beginning in the 1970s, brought the possibility of disturbance or auditory injury of bowhead whales by noise from seismic exploration, vessel traffic, and other industrial activity, a concern that now extends throughout the world's oceans and applies to all species of baleen whales (Richardson *et al.* 1995). Since the mid-1990s, there has been much concern about the impact of oil and gas development on the small population of gray whales that feeds in summer and fall off the northeastern coast of Sakhalin Island, Russia (Weller *et al*. 2002, Reeves *et al*. 2005).

The disturbance of whales by underwater noise (including masking of their vocalizations, impairment of their listening capabilities, and physiological stress) has lately become a much more salient issue for several reasons. First, efforts to monitor and measure ambient and anthropogenic underwater noise have increased and been enhanced by technologies that allow for greater geographical coverage, more extensive and sustained sampling, and more effective identification and localization of the animals. Second, commercial vessel traffic and offshore industrial, military, and extractive activities are increasing, especially near populated coastlines. Even near-pristine areas such as in parts of the Arctic, where seasonal sea ice cover is diminishing (see below), are experiencing a demand-driven rush to exploit previously inaccessible oil and gas and other mineral resources and an expansion in ship traffic (Reeves *et al.* 2014).

Much of the concern over acute sound impacts and the potential for death or injury of cetaceans has focused on active sources such as mid-frequency sonar used by military vessels and airguns used to conduct geophysical (seismic) surveys. Unusual mortality events associated with the use of mid-frequency sonar have primarily involved toothed cetaceans (odontocetes), and especially beaked whales (Cox *et al.* 2006, Nowacek *et al.* 2007, Hooker *et al.* 2012). Although two stranded common minke whales were involved in one of these incidents (Balcomb and Claridge 2001), the focus of concern over military sonar has been on beaked whales because they have been affected disproportionately (Moore and Barlow 2013).

Noise from seismic surveys is of greater concern for baleen whales. Although their hearing sensitivities are poorly known, their vocalizations tend to reside in the same low frequencies as the loud pulses produced by airguns, leading to concern over the potential to alter or disrupt behavior and even cause acoustic trauma—that is, "ear injury caused by a sudden and intense acoustic stimulus that causes a degree of permanent or temporary hearing loss" (Gedamke *et al.* 2011:496). A series of studies has shown behavioral changes in response to seismic noise, most notably in bowhead whales and gray whales (reviewed in Richardson *et al.* 1995, Gailey *et al.* 2007) and in humpback whales (McCauley *et al.* 2000), with the animals avoiding close approaches by operating airgun arrays and changing their surfacing, respiration, and dive behavior. Mitigation measures are often imposed by regulatory agencies (Nowacek *et al.* 2013). For example, delay or cessation of seismic operations is generally required when whales are observed close enough to the sound source to experience injury, *i.e.*, within "safety zones" calculated on the basis of the distance from the sound source at which received levels could lead to either temporary or permanent threshold shifts in the hearing of exposed animals (Southall *et al.* 2007). Also, "ramp up" and other procedures thought to encourage or allow whales to move away from disturbing sound sources are often included in the mitigation of noise impacts. There are likely other anthropogenic noise sources that affect baleen whales. For example, Risch *et al.* (2012) demonstrated that the low frequency pulses from an experimental sounder used to image fish shoals over a 100 km diameter area affected the singing of humpback whales roughly 200 km away.

Considerable effort has been made in recent years to understand the masking effects of elevated ambient sound levels on the ability of baleen whales to detect and project natural sounds (Clark *et al.* 2009, Ellison *et al.* 2011, Hatch *et al.* 2012, Moore *et al.* 2012*a*). Hatch *et al.* (2012) found that background noise levels from ship traffic in the Stellwagen Bank National Marine Sanctuary off Massachusetts had increased so much by 2008 that the contact-calling right whales in the area would have "lost 63% of the communication opportunities available to them in the mid 20th century" (Hatch *et al.* 2012:990). With the close passage of commercial vessels, the loss of "communication space" increased by as much as 67%. This loss of communication space and corresponding masking of other acoustic cues may affect intraspecific communication related to foraging, mother-young interactions, migration, and mate selection, as well as prey and predator detection and navigation (Hatch *et al.* 2012, Moore *et al.* 2012*a*). Rolland *et al.* (2012) concluded from measurements of stress-related fecal hormone metabolites (glucocorticoids) that exposure to low-frequency noise may be associated with chronic stress in North Atlantic right whales.

In addition to commercial shipping, seismic surveys, discussed earlier with regard to acute impacts, contribute to the increase in ambient sound levels in the ocean (Hildebrand 2009, Moore *et al.* 2012*b*). Gedamke[7] found that sounds from distant seismic survey activity increased background noise to levels that would reduce the potential for blue and fin whales (at 28 Hz and across a 20–30 Hz bandwidth) to communicate by 29%–40%.

In summary, concern has often been expressed in recent years about the largely unknown long-term and cumulative impacts of anthropogenic noise on cetaceans (as well as other marine life) (King *et al.* 2015). In our view, the noise-related issues that critically need additional study are (1) the nature and consequences of stress from noise on individual whales; (2) the role of noise in causing displacement from important habitat, *e.g.*, reduced time to feed; and (3) the masking of salient acoustic signals used by baleen whales for communication.

Pollution

Although a few studies of odontocetes and pinnipeds have demonstrated a causal relationship between contaminant exposure and impaired reproduction or immunosuppression (see Reijnders *et al.* 2009 for review), it is generally believed that because baleen whales tend to feed at lower trophic levels, they are less prone to uptake and bioaccumulation of pollutants (O'Shea and Brownell 1994, Weisbrod *et al.* 2000, Elfes *et al.* 2010). Tissue concentrations of organochlorines are lower in baleen whales than in toothed whales, a relationship that has been demonstrated both generally and in comparisons between those that inhabit the same ecosystem (Gauthier *et al.* 1997; Aguilar *et al.* 1999, 2002; Reijnders *et al.* 2009). Exposure to oil may cause respiratory problems in cetaceans (Venn-Watson *et al.* 2015), fouling of the baleen, and impacts on prey (Geraci and St. Aubin 1988). Long-term exposure to polycyclic aromatic hydrocarbons (PAHs) has been shown to lead to cancers in toothed whales (Martineau *et al.* 2002), but the consequences of such exposure for baleen whales are

[7]Personal communication from Jason Gedamke, Ocean Acoustics Program, Office of Science and Technology, NOAA Fisheries, 1315 East-West Highway Silver Spring, MD 20910, 15 May 2015.

not known (Angell *et al.* 2004, Pomilla *et al.* 2004). Biomarkers of exposure and biological response to PAHs in cetacean skin indicate that, unlike for contaminants that bioaccumulate, levels of these byproducts of fossil fuel production and consumption are comparable in baleen and toothed whales (Angell *et al.* 2004). There is also evidence that some populations living closer to industrial activity have higher levels of PAHs than more remote ones (Angell *et al.* 2004, Kraus and Rolland 2007).

Climate Change and Ocean Acidification

The potential direct and indirect effects of climate change on marine mammals, including baleen whales, have been widely discussed over the last decade (Learmonth *et al.* 2006, Simmonds and Isaac 2007, Moore and Huntington 2008, Tynan and Russell 2008, MacLeod 2009, Simmonds and Elliot 2009, IWC 2010, Kovacs *et al.* 2011, Gattuso *et al.* 2015).

Climate change-induced reductions in seasonal sea-ice and warming temperatures have spurred increasing industrial interest in the Arctic, thereby increasing the anthropogenic threats to Arctic cetaceans from ship strikes, pollution, and disturbance from underwater noise (Reeves *et al.* 2014). With regard to the direct effects of climate change on baleen whales, however, the prognosis may vary both within and across species. Bowhead whales, for example, do not have much possibility of northward range expansion in the face of warming ocean temperatures (Kovacs *et al.* 2011). On the other hand, while they are adapted to life in the ice, bowheads are also able to travel and feed independently of it. Despite the decline of sea-ice in the Chukchi and Beaufort seas over the past 20 yr, bowhead numbers have increased at about 3.7% per year (despite subsistence hunting) (Givens *et al.* 2013), their distribution and migration timing have not changed markedly (although they appear to arrive near Barrow earlier in the spring and to linger longer in the northeastern Chukchi Sea and western Beaufort Sea in the summer), and observations suggest that the seasonal opening of ice-free areas has improved feeding conditions for these whales (Moore 2009, Ashjian *et al.* 2010). Examination of body condition relative to available foraging habitat provides confirmation that more open water in the Beaufort Sea in the summer has resulted in healthier bowheads (George *et al.* 2005). Nonetheless, it remains to be seen whether, and to what degree, the changed trophic dynamics and ecosystem structuring under the new seasonally ice-free conditions and the shift to a more strongly pelagic ecosystem in the Arctic will affect bowhead populations over the long-term.

Another factor to consider in the Arctic is the arrival and more regular presence of seasonally migrant species that are responding to climate change by moving into higher latitudes. This will bring not only the potential for competition with bowheads, but also more predation by killer whales, exposure to novel pathogens, and impacts of invasive species on prey (Moore and Gulland 2014). The influx of new species will follow, and potentially influence, changes in trophic dynamics in the Arctic due to warmer water temperatures and reduced sea ice. Gray, fin, common minke, humpback, and killer whales have already expanded their ranges northward and into Arctic waters (Kovacs *et al.* 2011, Clarke *et al.* 2013). Such expansion does not necessarily represent a net benefit to such populations, at least in the short term. For example, the access of gray whales to summer feeding grounds in the Bering Sea and north of the Bering Strait continues to be limited by the timing of spring ice retreat at the southern limit of sea ice in the Bering Sea. In years of late ice retreat, the whales appear unable to compensate for lost feeding time and suffer reduced calf production and increased calf mortality (Perryman *et al.* 2002). Also, the timing of arrival in the southern portion of the southward gray whale migration was later in 1998/1999 in response to El Niño events, with corresponding reports of more calf births than normal north of the calving lagoons in Baja California, Mexico (Moore 2009). The expansion of range will not be only latitudinal. Reduced sea ice also may allow bowhead whale populations to mix more frequently across the Arctic than they have since the Little Ice Age from the 15th to the 19th century (Heide-Jørgensen *et al.* 2011, Alter *et al.* 2012).

There is also ample uncertainty with regard to the impacts of climate change on whales in the Southern Hemisphere. One analysis used climate models from the Fourth Intergovernmental Panel on Climate Change (IPCC) and information on distribution and feeding ecology to assess the impacts of a 2°C global warming on Southern Ocean cetaceans (Tynan and Russell 2008). Among projected changes were a decrease in the extent of sea ice and ice-edge habitat along the Antarctic continent and a southerly shift and shrinking of ocean fronts (*e.g.*, the Antarctic Convergence) which may in turn affect the availability of krill (Reid and Croxall 2001, Fraser and Hoffman 2003, Trathan *et al.* 2003). Tynan and Russell (2008) predicted that Antarctic minke whales, which forage along the Antarctic ice edges, will lose 5%–30% of their ice-associated habitat with this temperature increase. Migratory cetaceans will have to travel farther south (3°–5° of latitude) to reach the ocean fronts where they forage.

Some baleen whale populations are thought to be especially vulnerable because of cul-de-sac geography (Simmonds and Isaac 2007). For example, bowhead whales in the Sea of Okhotsk will likely be unable to shift northward to reach cold waters as ocean temperatures warm. Fin whales in the Mediterranean and resident fin whales in the Gulf of California may be limited by the enclosed geography of the seas they inhabit (Vidal *et al.* 1993, Panigada and Notarbolo di Sciara 2012). The Arabian Sea subpopulation of humpback whales and the northern Indian Ocean blue whale subspecies (*B. m. indica*) also appear to be "trapped." Both breed 6 mo out of phase with conspecific populations to the south and appear to be restricted to northwestern portions of the Indian Ocean. They follow a Northern Hemisphere breeding cycle and feed in the northern Indian Ocean during the austral summer, at the time when Southern Hemisphere humpback and blue whale populations to the south are feeding at the southern end of their annual migration in Antarctic waters (Mikhalev 1996, 1997; Minton *et al.* 2011). Individuals in these two northern Indian Ocean populations do not have the option of moving north in the face of warming temperatures; they are blocked from doing so by the continental mass of Asia. The notion that they could simply shift southward to find suitable habitat may ignore the drivers of prey abundance for these populations, which are likely the Northern Hemisphere monsoons that create regional upwellings and productive prey patches (de Vos *et al.* 2014). Changes in the timing and intensity of the monsoons may be more relevant to these and other Indian Ocean populations than changes in north-south seasonal temperature gradients. Global monsoon patterns are poorly understood and complex. Recent research on the substantial intensification of the Northern Hemisphere Summer Monsoon (which runs contrary to large-scale climate model predictions) from the 1970s to the present shows strong El Niño influences, overlain by multidecadal oscillations in the Atlantic, further influenced by "hemispherical asymmetrical global warming" (Wang *et al.* 2013). The net effect of climate change on a marine population in a cul-de-sac situation is not simple to predict.

The habitat of some species or subspecies judged to be tropical (*i.e.*, warm water-limited), such as Bryde's whales and dwarf minke whales, could expand, and the populations of some cosmopolitan species could be largely unaffected by climate change (MacLeod 2009). Recent extralimital records of baleen whales, such as gray whales in the Mediterranean Sea (Scheinin *et al*. 2011) and Namibia[8] and Bryde's whales in southern Californian waters (Kerosky *et al*. 2012), suggest that whales are responding to changing ocean conditions.

Baleen whales are likely to be negatively affected by ocean acidification even though, given the present state of scientific understanding, we can do little more than speculate on the mechanisms and levels of impact. A wide range of marine organisms, from planktonic coccolithophores and pteropods and other mollusks, to echinoderms, corals and coralline algae, build shells from calcium carbonate and are therefore at direct risk from ocean acidification (Doney *et al.* 2009). Changes in the survival and distribution of these organisms are expected to have major impacts on trophic dynamics and ecosystem processes over the next century (Fabry *et al*. 2008, 2009). These impacts are expected to be felt first in the Arctic and Antarctic seas which, due to cold water temperatures and other factors, have naturally low calcium carbonate concentrations (Orr *et al.* 2005, Fabry *et al.* 2009) and are predicted to become undersaturated with respect to aragonite by the end of this century. The effects of ocean acidification are anticipated to be both widespread and variable (Doney 2010). One major concern is that the biogeochemical, ecological and economic consequences of losing pteropods in the Arctic and Antarctic could have significant impacts on predators such as zooplankton, fish, seabirds, or cetaceans (Comeau *et al.* 2012, Mathis *et al.* 2015). The calcifying prey organisms of the northern Bering Sea that support higher trophic predators such as diving sea ducks, bearded seals (*Erignathus barbatus*), walruses, (*Odobenus rosmarus*) and gray whales may be at early risk from ocean acidification (Doney *et al.* 2009). There is little basis to evaluate the ability of such predators to modify their diets or otherwise respond to changes in availability of their primary prey (Fabry *et al.* 2009).

We conclude that as oceans warm and oceanic and meteorological conditions change, cul-de-sac or range-limitation conditions will come to represent major challenges for some populations. It must be acknowledged, however, that the baleen whales are capable of moving extremely large distances in short times to find shifting food resources and then return to distant breeding grounds. Their annual and seasonal movements already reflect an ability (whether acquired through selective forces over different climatic periods or learned within a few generations) to respond to considerable environmental variability. Reported range expansions (Kovacs *et al.* 2011, Clarke *et al*. 2013) and temporal and geographical overlap of previously discrete populations across the Arctic Ocean (Heide-Jørgensen *et al.* 2011, Alter *et al.* 2012) indicate some potential for adaptive responses in the face of climate change (Moore and Huntington 2008). Whether this potential extends to responding to the consequences of ocean acidification is an open question.

Conservation Status

Overview of Red List Status

Many of the "great whales" (meaning all baleen whales plus the sperm whale) were severely depleted in all oceans by commercial whaling, which ended

[8]http://namibiandolphinproject.blogspot.com/2013/05/a-rare-and-mysterious-visitor-in-walvis.html.

(almost but not quite entirely) in 1986 with implementation of the IWC's global "moratorium" on commercial whaling. The legacy of commercial whaling continues to exert a strong influence on how the conservation status of species and populations is assessed. For example, blue, fin, sei, and North Pacific right whales are classified on the IUCN Red List as Endangered based primarily on their global declines from whaling. The other Endangered baleen whale species, the North Atlantic right whale, was also nearly annihilated by whaling, which began in the northeastern Atlantic in the 11th century or earlier and continued into the 20th century. This species' recovery has been slowed considerably by ship strikes and entanglements in fishing gear so its current status is influenced not only by the decline caused by whaling but also by these ongoing threats. A blue whale subspecies, the Antarctic blue whale (*B. m. intermedia*), and a North Pacific right whale subpopulation (eastern) are listed as Critically Endangered because their numbers were driven to very low levels by commercial whaling and remain there. In recent years Antarctic blue whales have been increasing at about 8.2% per year but their total abundance in 1998 was still only about 1% of what it was before whaling.

Several baleen whale populations have been recovering from the depletion caused by commercial whaling. The bowhead whale, southern right whale, common minke whale, humpback whale, and gray whale are classified as Least Concern, indicating that at the species level they do not meet any of the criteria for threatened status. In each of these cases, increased numbers across the total range have been sufficient to push the species as a whole above the threshold for threatened listing. Nevertheless, some subpopulations of these Least Concern species—western Pacific gray whales, Arabian Sea humpback whales, Oceania humpback whales, Peru-Chile right whales, and Svalbard/Barents Sea and Sea of Okhotsk bowhead whales—remain at low levels and are listed separately as either Endangered or Critically Endangered. The common minke whale was heavily exploited in parts of its range during the second half of the 20th century but was, overall, less severely depleted by commercial whaling than the larger, more individually valuable baleen whales.

Four species of baleen whales, the Bryde's whale, Omura's whale, pygmy right whale, and Antarctic minke whale, are listed as Data Deficient, meaning available information is inadequate for a conclusive assessment of status. Despite having the same assigned status, there are major differences among these species with regard to the type of information that is lacking. In the case of the Bryde's whale, the problem resides mainly in systematics and taxonomy and therefore how to define units for assessment not only at the species level but also at the population level and how to allocate the large historical catches in some areas (*e.g.*, the North Pacific) when estimating population trends. Omura's whale was described and named in 2003 and very little is known about its distribution, ecology, and basic biology, but it is generally believed that this species was never heavily exploited. The pygmy right whale, the smallest baleen whale, is restricted to the Southern Hemisphere. It was rarely the target of whalers and little is known about it. Antarctic minke whales are still classified as Data Deficient although, as explained later, some progress toward resolving the relevant uncertainty has been made since 2008.

Species-level assessments of the baleen whales are problematic. All species listed as Least Concern have subpopulations that are at risk. Some species assigned to a threatened category (Endangered or Vulnerable) include subpopulations that are nonthreatened. Assigning a single "global" status to what are very widespread (in some cases cosmopolitan) meta-populations tends to disguise the highly variable status of local,

Table 1. Red List status of baleen whale species and those subspecies and subpopulations that have been assessed.

Taxa or conservation units	Critically Endangered	Endangered	Vulnerable	Least Concern	Data Deficient	Unassessed
Species	0	5	0	5	4	0
Subspecies	1	0	0	0	1	12
Subpopulations	4	3	1	1	0	uncertain

regional, and even basin-scale populations (subpopulations in Red List terms) (IUCN 2012). While there is interest in making species-level comparisons when evaluating global biodiversity trends for terrestrial and marine mammals (Schipper *et al.* 2008, Kovacs *et al.* 2012), such comparisons can break down at the subspecies and subpopulation levels. In the case of baleen whales, the universe of such units is indeterminate; in other words, it is not feasible at present to establish how many subspecies and subpopulations there are. The number of identified subpopulations increases steadily as genetic and other research reveals more about population structure. Also, only a relatively small subset of those units that are recognized has been assessed for the Red List. The Cetacean Specialist Group has taken a selective, hierarchical approach when setting priorities for assessment, based primarily on indications of conservation concern from its expert members, and this has meant that most of the assessed subspecies and subpopulations are ones already suspected of being threatened. In other words, many subpopulations (if not also subspecies) that would be considered non-threatened have never been assessed; only one subpopulation (Bering-Chukchi-Beaufort Sea bowhead whales) has been assessed as Least Concern and one subspecies (pygmy blue whale) as Data Deficient (Table 1). Finally, not all subspecies are sufficiently well described to be considered appropriate units of concern for conservation. In contrast, subpopulations (or in IWC terms, stocks) are recognized as such because they are geographically or demographically distinct and are perforce units to conserve (Taylor 2005).

Current Status of Species, Subspecies, and Subpopulations

In the course of this review, we considered information on all baleen whale species, subspecies, and subpopulations that had been assessed for the IUCN Red List, subspecies that had not been assessed but were recognized by the Committee on Taxonomy (2015),[9] and stocks recognized by the IWC Scientific Committee (Table S1).

Blue, fin, and sei whales were decimated throughout their ranges by commercial whaling, and their populations have followed broadly similar trajectories. We provide a detailed treatment of blue whales here to illustrate the impact of commercial whaling on them and several other species as the whaling effort moved from region to region. This section also shows some of the complexities of identifying and defining stocks and the difficulty of determining abundance levels and population parameters

[9]Current at October 2014; see http://www.marinemammalscience.org/index.php?option=com_content&view=article&id=714&Itemid=340.

for baleen whales even with recently developed tools in genetics, satellite tracking, statistical analysis, and acoustic monitoring.

Blue Whale

Since they provided the largest yield per unit of hunting effort, blue whales were the most valuable and thus were among the first whales to be depleted by modern commercial whaling, which began in Norway in the 1860s and had spread to all oceans, including the Antarctic, by the early 20th century. Although blue whales have been legally protected by the IWC for over half a century, beginning in 1955 in the North Atlantic (although Denmark and Iceland continued to take blue whales there under formal objection to the protection provision until 1960) (Committee for Whaling Statistics 1962), 1966 in the North Pacific, and 1965 in the Antarctic, the depletion in most of the range was severe, and evidence of population increase has been spotty and often equivocal. Also, illegal or pirate hunting of blue whales continued into the early 1970s, mainly by the Soviet Union (Ivashchenko *et al.* 2011) but also by other countries operating without regard to IWC regulations, and this further depleted or at least stalled the recovery of some populations and depleted most of the Southern Hemisphere pygmy blue whale populations (Branch *et al.* 2007*a*).

In the North Atlantic, at least 11,000 blue whales were killed between the late 19th century and 1960 (Jonsgård 1977). Despite full protection since 1960, the North Atlantic population does not appear to have increased to anywhere near its former size. Abundance estimates for the Gulf of St. Lawrence are around 400 whales based on photo-identification studies (Ramp *et al.* 2006). Estimates for the central North Atlantic, which includes the waters around Iceland, East Greenland, Jan Mayen, the Færoes, and the British Isles, have ranged between 222 (95% CI 115–440) in 1987 and 979 (95% CI 137–2,542) in 1995 (Pike *et al.* 2009). Observations of blue whales off Norway and especially northern Norway where substantial numbers were taken in the late 19th and early 20th centuries (Jonsgård 1977) are now very rare (Christensen *et al.* 1992).

In the North Pacific, blue whales were hunted extensively in the 20th century with 9,773 reported taken between 1905 and 1971. In addition, a significant proportion of the whales killed but not assigned to species between 1900 and 1936 were blue whales (Ohsumi and Wada 1972, Reilly *et al.* 2008*a*, Monnahan *et al.* 2014*a*). At least two blue whale subpopulations are extant in the North Pacific (Stafford *et al.* 2001, Gilpatrick and Perryman 2008, Monnahan *et al.* 2014*a*). Blue whales in the far west, including off Japan, appear to have been extirpated as there have been no reports of kills, sightings, or other evidence there for over 50 yr (Clapham *et al.* 2008). A recent abundance estimate for the eastern North Pacific is 2,497 (CV = 0.24) (Calambokidis *et al.* 2009) and it has been suggested that blue whales in this region are approaching pre-exploitation numbers (Monnahan *et al.* 2014*b*). No subpopulations in the North Pacific have been assessed for the IUCN Red List. The greatest threat identified for individual blue whales in the eastern North Pacific is ship strikes although there is evidence suggesting that the current rate of ship strikes does not have a population-level impact (Monnahan *et al.* 2014*b*). There is also growing concern about the ever increasing amount of anthropogenic noise in their environment, especially their feeding grounds along the southern California coast (McKenna 2012*a*).

The Antarctic blue whale subspecies is redlisted as Critically Endangered (Reilly *et al.* 2008*b*). In an assessment of Antarctic blue whales, the 1905 population (before the start of commercial whaling) was estimated at 239,000 (202,000–311,000) whales compared with a 1996 estimate of 1,700 (860–2,900) (Branch *et al.* 2004). A newer estimate of this subspecies is 2,280 (1,160–4,500) in 1998 (Branch 2007), which is still less than 1% of the prewhaling abundance. If commercial exploitation of krill in the Antarctic expands in the future, it could have a strong effect on Antarctic blue whales, as could any major change in krill availability due to climate change (Reid and Croxall 2001, Fraser and Hoffman 2003, Trathan *et al.* 2003).

Another subspecies, the pygmy blue whale, is considered Data Deficient (Cetacean Specialist Group 1996*a*).[10] This subspecies (*B. m. brevicauda*) was described from a specimen taken southwest of the Prince Edward Islands in the southwestern Indian Ocean (Ichihara 1966) and other specimens of "pygmy" like blue whales have since been reported from various locations in the Southern Hemisphere and the Arabian Sea. Pygmy blue whales were exploited starting in the late 1950s to the late 1960s when almost 13,000 individuals were killed (Branch *et al.* 2004).

LeDuc *et al.* (2007) showed that the populations of pygmy blue whales in at least two regions (Western Australia and Chile–Peru) are as different from each other as either is from the Antarctic blue whale. Branch *et al.* (2007*b*) proposed, and the Committee on Taxonomy (2015) accepted, that the blue whales off Chile and probably Peru constitute an unnamed subspecies. Thus, the suite of populations referred to as pygmy blue whales, differentiated on the basis of genetic profiles and call types, may consist of separate subspecies or subpopulations, each with a different history of exploitation and depletion (Brownell *et al.* 2015). Regardless of their taxonomic rank, these populations should be assessed individually.

Off Western Australia, whales genetically identified as pygmy blue whales are best known from Geographe Bay and Perth Canyon in the west (Attard *et al.* 2012) to Bass Strait in the east (Gill *et al.* 2011). Blue whales off the west coast of Australia migrate north into the Banda Sea, around Timor, Indonesia (Double *et al.* 2014). Their abundance has been estimated as 662–1,559 based on passive acoustics (McCauley and Jenner 2010) and 712–1,754 based on photographic mark-recapture (Jenner *et al.* 2008). Most of the exploitation of this group of blue whales was by Soviet pelagic operations in the 1960s (Mikhalev 1996). Chittleborough reported that "pygmy blue whales have been captured along the western coast of Australia in recent years," including a single whale landed at the whaling station of Carnarvaron, Western Australia, in May 1959 (Chittleborough in Ichihara 1966:82). The population has not been assessed separately for the Red List, at least partly because the Soviet catches of pygmy blue whales have not yet been allocated to subpopulations (also see Zemsky and Sazhinov 1994). Moreover, the population structure of pygmy blue whales in the Indian Ocean is poorly known. Based on call types, there is likely more than one Indian Ocean subpopulation in addition to the one in the Arabian Sea, at least one in the west and one in the east (Stafford *et al.* 2011).

Almost 3,000 blue whales were taken off Chile from 1926 to 1971, more than a third of them in the 1960s (Aguayo L. 1974). Williams *et al.* (2011) estimated 303 (CI 95% 176–625) blue whales off Chile in December 1997, and Galletti Vernazzani *et al.* (2012) identified 363 different blue whales in this region between 2004 and 2010. The main feeding area for these whales is the nearshore waters off the north-

[10]The pygmy blue whale subspecies was assessed as Data Deficient in 1996. Based on a more recent species-level assessment, which included pygmy blue whales, the blue whale is currently listed as Endangered (Reilly *et al.* 2008*a*).

west coast of Isla Grande de Chiloe (Galletti Vernazzani *et al*. 2012). Ship strikes are a concern for this subpopulation because of the increasing presence in the region of both cargo and cruise ships (Brownell *et al.* 2009, 2014). Recently, a match (both photographic and genetic) was made for a female sampled first near the Galápagos and then in the Gulf of Corcovado, Chile, just south of Chiloe (Torres-Florez *et al*. 2015). This is the first link between the feeding area and the likely the breeding area for this population.

No blue whale calls have been recorded in the South Atlantic, but a few specimens of pygmy blue whales, amongst a predominance of Antarctic blue whales, were taken at South Georgia and logged as "myrbjønners"—described as a "distinct race" of small blue whales with a large quantity of pale spots on the dorsal surface (Mackintosh 1942, Fraser in Ichihara 1966). In the eastern South Atlantic, most of the blue whales taken off the west coast of Africa (Congo, Angola and Namibia, and western South Africa) were Antarctic blue whales; however, based on their length frequencies, a small portion (3.9%) may have been pygmy blue whales (Branch *et al.* 2008 and see Bannister and Grindley 1966).

Blue whales have been documented almost year-round in New Zealand waters through sightings and acoustic recordings (Miller *et al*. 2014; Torres *et al.* 2014; Olson *et al*., in press). Pygmy blue whales (New Zealand, Call Type 3) are known from both eastern and western coasts of the North Island and the South Island as well as from the South Taranaki Bight (Torres 2013; Torres *et al*. 2014; Olson *et al*., in press). Feeding behavior has been observed in the Hauraki Gulf and off the eastern and western coasts of the South Island (Olson *et al*., in press). Limited Soviet catches were made in the 1960s around the North Island and the northern half of the South Island (Mikhalev 2000). A ship strike has been reported off the coast of Auckland (Torres 2013). Also, there has been significant growth in the offshore oil and gas exploration around New Zealand, including frequent and extensive seismic surveys and drilling of test wells (Torres 2013, Torres *et al*. 2014). On the Australian coast of the Tasman Sea blue whale strandings and sightings are rare (Anonymous 1954). Blue whales in this region have not been assessed.

Blue whale sightings around New Caledonia and the Solomon Islands region of the Coral Sea are rare. Ohsumi and Shigemune (1993) reported that 21 groups (41 individuals) were observed near the Solomon Islands in August 1957 and Frank and Ferris (2011) recorded blue whale vocalizations in the Solomon Sea in 1999. However, no blue whales were observed in the region during cruises in 1993 and 1994 (Shimada and Pastene 1995, Goto *et al*. 1995). Blue whale records on the Coral Sea coast of Australia are rare. Illegal Soviet pelagic whaling is known to have occurred around New Zealand during the 1960s and would have depleted the blue whales there, but it is not known if the whales near the Solomons are connected to those in New Zealand. If so, this could explain their absence around the Solomon Islands in the 1960s (IWC 1996).

The blue whales, likely pygmy blue whales, that feed over the Madagascar Plateau in the western Indian Ocean are another enigma. Best *et al.* (2003) estimated 424 pygmy blue whales south of Madagascar from a survey in December 1996. The range of this population is much larger than the area surveyed and therefore that number should not be considered a population estimate. It is likely that the Madagascar whales are part of the population hunted in the western Indian Ocean during the late 1950s and 1960s by both Japanese and Soviet pelagic whaling operations, mainly around the Prince Edward Islands and east to 55°E (Ichihara 1966, Mikhalev 1996).

The northern Indian Ocean (Arabian Sea) blue whale (*B. m. indica*) has not been assessed as no current abundance estimate is available (Anderson *et al*. 2012). During four seasons (1963–1966), illegal Soviet pelagic whaling operations killed 1,294 blue whales off the Seychelles and Maldives, in the Gulf of Aden, and south to the west coast of India and Sri Lanka (Mikhalev 1996). Recent reports of fatal ship strikes on blue whales in the shipping lanes off southern Sri Lanka highlight the importance of assessing this subspecies (De Vos *et al.* 2013). Due to its limited range, heavy past exploitation, and ongoing ship strikes, this may be the most at-risk blue whale population.

Fin Whale

Fin whales were first targeted in the North Atlantic in the 1870s and more than 72,000 were reportedly taken there between 1900 and 1999 (Rocha *et al.* 2014). More than 725,000 and 74,000 were reported as having been killed in the Southern Hemisphere and North Pacific, respectively, between 1905 and 1976 (Rocha *et al.* 2014). As explained in detail by Rocha *et al.* (2014), catch records of fin and sei whales are confounded by the fact that, at times, the Soviet Union overreported catches of fin whales to cover up illegal catches of other species and to make oil production figures consistent in reports to authorities. The Red List assessment used an estimate of 53,000 fin whales in the North Atlantic in 2000, 17,000 in the North Pacific in 1975, and somewhat more than 15,000 in the Southern Hemisphere in 1983 to determine that the global population had declined by more than 70% over the preceding three generations (1929-2007) (Reilly *et al*. 2008*c*). Fin whales may be increasing in most areas given that they are now protected from commercial whaling in all of their range except off Iceland. Trend data indicate that they are increasing in the North Pacific (Zerbini *et al.* 2006, Moore and Barlow 2011).

The Mediterranean subpopulation, which is redlisted as Vulnerable, is genetically differentiated from fin whales elsewhere in the North Atlantic (Panigada and Notarbartolo di Sciara 2012, also see Castellote *et al*. 2012) and estimated to be in excess of 3,500 animals (Forcada *et al.* 1996). The cumulative effects of a variety of threats in this semienclosed basin (entanglement, anthropogenic noise, ship strikes, pollution) are thought to be inhibiting recruitment and adding to mortality in the Mediterranean subpopulation. Two other areas where fin whales merit assessment at the subpopulation level are the Gulf of California (Mexico) and East China Sea (Reilly *et al.* 2008*c*). The latter population was heavily exploited by commercial whaling before 1960.

Sei Whale

Hunting of sei whales started in the North Atlantic in the late 1800s off Norway and it continued there until the 1950s and off Iceland mainly after the 1950s and until 1989. They were also hunted off Nova Scotia, Newfoundland, the Shetlands, Hebrides, Færoes, and Spain from land stations. In the North Pacific, sei whales were being taken in northern Japanese waters by 1910 (Andrews 1916) (some of the whales reported were Bryde's whales; Omura 1977) and off California in the 1920s (Clapham *et al*. 1997). With the depletion of blue whales and then fin whales, both pelagic and land station operations started to concentrate on sei whales in the Southern Ocean and North Pacific. Large catches of sei whales (>1,000 per season) were made during pelagic operations in the Southern Hemisphere, beginning in the 1959/1960 season and reaching a peak in the 1964/1965 season when 17,721 were killed (Horwood 1987). The peak catch in the South Atlantic at South Georgia land stations was 1,183 whales during the 1949/1950 season (Horwood 1987). Populations worldwide were seriously depleted by the mid-1970s. With limited or no survey effort for sei whales in either the Southern Hemisphere or North Pacific, there is no basis to determine whether, or to what extent, populations in either ocean have increased since the end of commercial whaling. The Red List assessment used estimates of 12,000 sei whales in the North Atlantic in 1989, 8,600 in the North Pacific in 1974, and 11,000 in the Southern Hemisphere in 1979 to determine that the global population had declined by more than 70% over the last three generations (1930–2007), thus warranting an Endangered status for the species (Reilly *et al.* 2008*d*).

In 2015 the IWC Scientific Committee accepted a 2010–2012 abundance estimate of 29,632 (CV = 0.242; 95% CI 18,576–47,267) for sei whales in the North Pacific (IWC, in press). However, there is no current agreement on the stock structure of sei whales in the North Pacific. From 2004 through 2013, 100 sei whales were taken per year in Japan's western North Pacific research whaling program called JARPN II (Pastene *et al.* 2009). Starting in 2014, Japan reduced the offshore component of JARPN II from 100 to 90 sei whales (IWC 2015:65).

Bryde's Whale

Catch histories for sei and Bryde's whales are confused because the literature and IWC records lumped them as a single species in early years and catch records in the western North Pacific were only recently segregated by species. Bryde's whales are redlisted as Data Deficient (Reilly *et al.* 2008*e*). From the early 1970s and until fairly recently, they were considered to comprise a single species, *Balaenoptera edeni*, but increasingly *B. edeni* has been used for the small coastal form found in the western Pacific and Indian oceans and *B. brydei* for the larger, more oceanic form found in temperate and tropical waters of the Atlantic, Pacific, and Indian Oceans. LeDuc and Dizon (2002) suggested that these two forms be considered full species. However, Kato and Perrin (2009) noted that the differences between them are closer to what are now considered to be subspecies. A recent genetic analysis of specimens from Oman, the Maldives, Bangladesh, Java (Indonesia), and the northwestern Pacific identified two subspecies: *B. edeni brydei* and *B. edeni edeni* corresponding to the two forms mentioned above (Kershaw *et al.* 2013). The same study distinguished "distinct population units" (which should be considered units for conservation) within each of the subspecies. Similarly, Rosel and Wilcox (2014) found that the small population resident year-round in the northeastern Gulf of Mexico is genetically distinct from other members of the Bryde's whale complex examined to date.

There is a long history of shore-based whaling for Bryde's whales in Japan going back to at least 1910 (Omura 1977) and probably to the start of modern commercial whaling in Japan around 1900. In the North Pacific, Soviet and Japanese factory ships took large numbers of Bryde's whales in the mid 1970s after all the other larger baleen whales had been depleted (IWC 1997, Danner *et al.* 2006). Substantial numbers (848) were taken by illegal pelagic whaling operations in the Arabian Sea during a few years in the 1960s (Mikhalev 2000). In the Southern Hemisphere, mainly between the 1950s and 1970s, large numbers of Bryde's whales were taken by shore-based whaling operations in places such as Iquique and Valparaiso, Chile (Aguayo L. 1974); Paita, Peru (Valdivia *et al.* 1981); Costinha and mainly Cabo Frio, Brazil (Williamson 1975); Cape Lopez, Gabon (Budker 1951); and Durban and Saldanha Bay (Donkergat), South Africa (Olsen 1913, Best 1977). Also in the 1970s, Japan started "research whaling" (under special permits issued by the national government for 3 yr) in tropical portions of the western Pacific and eastern Indian oceans where they took about 450 whales (Ohsumi 1980). Now research whaling is limited to the northwestern Pacific (50/yr). Bryde's whales are also subject to bycatch and ship strikes in much of their range. As with other species, it is important to manage human activities on the basis of distinct, demographically independent populations such as those provisionally identified in the Maldives, Java, and northwestern Pacific and in the northern Indian Ocean and coastal waters of Japan (Kershaw *et al.* 2013).

Omura's Whale

Omura's whale appears to be restricted to warm-temperate and tropical Indo-Pacific waters on both sides of the equator but the vast majority of records are from the Northern Hemisphere. It is one of the least known baleen whales (Sasaki *et al.* 2006, Yamada 2009); a new population was recently discovered off the northwestern coast of Madagascar (Cerchio *et al.* 2015). The full range of the Omura's whale has yet to be determined, but is thought to be smaller than that of any other baleen whale. Few catch records are available, in part because of the past problems with species identification. The numbers of Omura's whales killed by Japanese operations, including during research whaling in the Indo-Pacific (Wada *et al.* 2003) and possibly by small-type whaling in southwestern Japan, are believed to have been low, but even small levels of removals could have affected small, localized populations. This species is red-listed as Data Deficient (Reilly *et al*. 2008*f*).

Common Minke Whale

Until the late 1990s, only one species of minke whale was recognized. Most of the scientific literature prior to that time used the name *B. acutorostrata* for all minke whales including Antarctic minke whales. Since 2000, the IWC has recognized the Antarctic minke whale (*B. bonaerensis*) as a separate species (Rice 1998, Brownell *et al*. 2000). In addition, Best (1985) and Arnold *et al.* (1987) identified and described a dwarf form of minke whale in the Southern Hemisphere on the basis of morphology and coloration. In the early 1990s the dwarf minke whale of the Southern Hemisphere was assigned to *B. acutorostrata* based on genetic analyses (Pastene *et al.* 1994), but these dwarf minke whales are not the same as the Northern Hemisphere form of the species and therefore are considered to represent an unnamed and undescribed subspecies (Committee on Taxonomy 2015). Because of their wide distribution in the Southern Hemisphere, dwarf minke whales likely occur as multiple subpopulations and as such they need to be managed and assessed separately. The minke whales in the North Pacific are usually referred to as *B. a. scammoni*, but this subspecies is based on a fossil and more research is needed to understand and describe the populations or subspecies that occur in the North Pacific.

In the North Pacific, common minke whales are best known from the Sea of Okhotsk, Sea of Japan, off the Pacific coast of Japan, the Yellow Sea and the East China Sea. Those in the Sea of Okhotsk and off northern Japan number about 25,000 (CV = 0.316) (Buckland *et al*. 1992). The minke whales within this region are divided by the IWC into two units, O (Okhotsk) stock and J (Japan) stock. The J-stock is found mainly in the East China Sea, Yellow Sea, and Sea of Japan and the O stock is found in the Sea of Okhotsk and off the Pacific coast of Japan. The 25,000 estimate refers mainly to the O-stock.

The autumn-breeding J-stock, centered mainly in coastal waters of the Sea of Japan and along the Pacific coast of Japan, is of the greatest immediate conservation concern. No abundance estimate is available over the entire range of this stock, but various regional surveys indicate a total of around 4,500 animals (Miyashita and Okamura 2011). Small numbers are taken in Japanese research whaling operations and hundreds are taken each year as bycatch in fishing gear off South Korea, Japan, China, and perhaps North Korea. It is important to regard official catch reports critically as genetic analyses indicate that the number of animals actually taken in Japan and South Korea is considerably higher than reported (Baker *et al*. 2007). In addition, each year some level of illegal whaling from J-stock is reported to the IWC by South Korea. The IWC classifies the J-stock as a "Protection Stock" because of its depleted status (IWC 2013*c*:176), and Red List documentation refers to it as a "distinct subpopulation" (Reilly *et al*. 2008*g*). However, it has not been assessed for the Red List; therefore assessment of this stock should be a high priority.

All minke whales in the central and eastern North Pacific are currently called the "Remainder" stock by the IWC, but this large region is poorly studied. Minke whales occur in low numbers in tropical waters around the Hawaiian Islands from about November to March. There is no abundance estimate for this region. In the eastern North Pacific, minke whales range from the Bering Sea south to Baja California, Mexico, but they do not appear to be abundant, with only about 2,000 in the central and southeastern Bering Sea (Moore *et al*. 2002) and another 1,000 along the west coast of North America (Forney 2007).

Common minke whales are widespread and abundant in the North Atlantic, numbering perhaps 180,000 (Reilly *et al.* 2008*g*). Aboriginal subsistence whaling for this species off East and West Greenland (Denmark) is managed under the IWC and commercial whaling by Norway and Iceland is carried out under objection to the IWC commercial moratorium.

The dwarf minke whale was never hunted commercially (Kato and Fujise (2000), but at least a few individuals were taken in the large commercial hunt for Antarctic minke whales from 1971 to 1986. Sixteen dwarf minke whales were reported as taken in Japan's "scientific" whaling between the 1987/1988 and the 1992/1993 Antarctic whaling seasons (Nishiwaki *et al.* 2005) and all but one of these were killed in latitudes between 62°S and 55°S, the northern limit of Japan's Antarctic research whaling operations.

Antarctic Minke Whale

The stock structure of Antarctic minke whales is poorly understood, but the aggregate abundance of the species is in the hundreds of thousands. Factory-ship whaling in the Antarctic turned to minke whales in 1971 and nearly 100,000 have been taken there since then. An additional 14,000 were taken at a Brazilian land station (Costinha) from 1964 to 1985 (Reilly *et al.* 2008*h*). Factory-ship whaling has continued at a lower level since 1987/1988 under special permits issued by Japan, with catches concentrated in certain areas (*e.g.*, IWC Antarctic Areas III, IV, and V). Analyses of two survey programs (CPII 1985/86–1990/91, CPIII 1992/93–2003/04) have sought to determine whether a difference in estimates—around 720,000 (95% CI 512,000–1,012,000) in CPII *vs.* 515,000 (95% CI 361,000–733,000) in CPIII (IWC 2013*b*)—indicates a real decline in abundance or reflects a problem with survey methodology (IWC 2013*b*). In 2012 the IWC Scientific Committee concluded that although it could agree on the estimates of abundance "within the areas surveyed in CPII and

CPIII," it could not reach a conclusion on "whether (and if so to what extent) these numbers indicate a real decline . . . between the two periods of the two surveys" (IWC 2013*b*:29). Further, the committee was "unable to exclude the possibility of a real decline in minke whale abundance between CPII and CPIII" (IWC 2013*b*:29). Williams *et al.* (2014) discussed the difficulties of detecting abundance trends from open-water surveys in Antarctic waters.

Humpback Whale

The humpback whale is redlisted as Least Concern because of its strong recovery in many parts of its global range (Reilly *et al.* 2008*i*, Fleming and Jackson 2011), with aggregate numbers currently estimated at 110,000+. This figure is derived from the IWC estimates, by stock, totaling more than 80,000 for the Southern Hemisphere (Table 2; seven stocks, including the Arabian Sea), 10,290–13,390 for the North Atlantic in 1993 (Stevick *et al.* 2003 and see Ryan *et al.* 2014; one stock), and 21,063 for the North Pacific in 2006 (Barlow *et al.* 2011; basin-wide estimate from multiple feeding and breeding areas). Humpback whales continue to be hunted regularly only in Greenland and Bequia (St. Vincent and the Grenadines); in both areas the removals are reported to the IWC and subject to catch limits determined by the IWC Scientific Committee.

The Endangered Arabian Sea subpopulation of humpback whales is geographically, demographically, and genetically discrete (Minton *et al.* 2008, 2011; Rosenbaum *et al.* 2009; Pomilla *et al.* 2014). Its year-round residency in a subtropical region makes it unique among humpback whale populations. Unlike the Southern Hemisphere humpback whales to the south, the Arabian Sea whales are on a Northern Hemisphere breeding cycle (Mikhalev 1997, Minton *et al.* 2011). After being nearly extirpated by illegal Soviet whaling in the 1960s (238 were killed in 1966 alone) (Mikhalev 1997, 2000), population recovery has been hampered by the continuing problem of entanglement in fishing gear and likely also ship strikes (Minton *et al.* 2008, 2011). Based on mark-recapture estimates of fewer than 100 whales along the coast of Oman, Minton *et al.* (2008, 2011) concluded that there were fewer than 250 mature individuals in the entire Arabian Sea.

The Oceania subpopulation of humpback whales (breeding stocks E and F, combined; see Table 2) is redlisted as Endangered because at the time of the most recent formal Red List assessment it was thought to have declined by more than 70% within the preceding three generations (*i.e.*, since 1942) (Jackson *et al.* 2006, Childerhouse *et al.* 2008). In the light of further assessment work by the IWC Scientific Committee, it has become clear that a new assessment is needed. The links between whales migrating past eastern Australia and those migrating past New Zealand and/or New Caledonia as well as their connections with the whales that occur near Tonga and French Polynesia require re-examination (Valsecchi *et al.* 2010, Steel *et al.* 2014). The Oceania subpopulation was estimated to number 4,300 whales in 2005 (Constantine *et al.* 2012). It has been suggested that the rarity of whales in some formerly populous breeding habitats in Oceania (*e.g.*, Fiji) does not necessarily represent a failure to recover, but could instead indicate a redistribution of animals as they seek out more populous mating grounds. This might also explain "above the maximum plausible" rates of increase observed in other places (*e.g.*, eastern Australia) (Clapham and Zerbini 2015).

In part because of the increasing numbers of whales and in part because of concomitant increases in vessel traffic and changes in fishing activity in their habitat,

Table 2. Humpback whale stocks and abundance estimates. (A detailed breakdown for North Pacific subpopulations is in Table S1).

Breeding stock	Area	Estimate	Year of estimate	Citation
Breeding stock A, Western Atlantic Ocean	Brazil	6,300 (95% CI = 4,300–8,600)	2005	Andriolo *et al.* (2010)
Breeding stock B, Eastern Atlantic	Gabon (substock B1)	6,800 (95% CI = 4,350–10,400)	2005	Collins *et al.* (2010)
	West South Africa (substock B2)	300 (95% CI = 200–400)	2001	Barendse *et al.* (2011)
Breeding stock C, Western Indian Ocean	Mozambique (substock C1)	6,000 (95% CI = 4,400–8,400)	2003	Findlay *et al.* (2011)
	Madagascar (substock C3)	7,500 (95% CI = 2,100–12,700)	2004	Cerchio *et al.* (2009)
Breeding stock D, Eastern Indian Ocean	Western Australia	28,800 (95% CI = 23,700–40,100)	2008	Hedley *et al.* (2011)
Breeding stocks E and F, Western/Central South Pacific	Eastern Australia (substock E1)	14,500 (95% CI = 12,700–16,500)	2010	Noad *et al.* (2011)
Breeding stock G, Eastern South Pacific	Ecuador	6,500 (95% CI = 4,300–9,900)	2006	Felix *et al.* (2011)
Arabian Sea		80 (95% CI = 60–110)	2004	Minton *et al.* (2011)
North Atlantic		11,570 (95% CI = 10,290–13,390)	1992/1993	Stevick *et al.* (2003)
North Pacific		21,063 (95% CI = 20,099–23,552)	2006	Barlow *et al.* (2011)

ship strikes and entanglements of humpbacks are occurring with greater frequency in many areas, *e.g.*, the western North Atlantic (Robbins *et al.* 2007; Robbins 2008, 2009); Ecuador (Félix *et al.* 2011); the Arabian Sea (Minton *et al.* 2011). It is difficult to separate, measure, and assess the factors most responsible for the high rates of mortality and injury, but there is reason for concern that in some regions at least, human activities are limiting or even preventing population recovery (Fleming and Jackson 2011). Offshore oil and gas development is intensive and expanding in many of the breeding and feeding areas of humpback whales, such as off the west coast of Africa, and this could be a significant source of disturbance to the animals in such areas (Rosenbaum *et al.* 2014).

Besides those in the Arabian Sea, the humpback whales in greatest need of assessment are in the western North Pacific (west of 180°) (Brownell *et al.* 2010, Baker *et al.* 2013) and eastern North Atlantic (IWC 2002). In both areas, numbers and densities are thought to be far below historical levels and we lack sufficient information to evaluate trends. In addition, judging by information in annual progress reports to the IWC, the number of humpback whales that die in fishing gear in Japan appears to be increasing.

In the eastern North Atlantic, there is evidence of substantial whaling for humpback whales around the Cape Verde Islands during the 19th century (Reeves *et al.* 2002). Recent observations suggest that the subpopulation breeding there is far too small to account for the relatively large numbers observed in the central and eastern North Atlantic feeding grounds off Iceland and Norway (Ryan *et al.* 2013, 2014). There has been considerable discussion within the IWC Scientific Committee concerning genetic evidence of at least one additional breeding area (*i.e.*, in addition to the well-known area in the northern Antilles off Hispaniola and Puerto Rico) for humpback whales that feed in the north-central and northeastern North Atlantic. One of these appears to be the Cape Verde Islands but recent evidence suggests a tendency for the whales wintering in the southeastern Caribbean (*e.g.*, around Guadeloupe and Trinidad) to also migrate to feeding grounds (Iceland-Norway) in the northeastern North Atlantic (Stevick *et al.* 2015).

Bowhead Whale

The IWC recognizes four stocks of bowhead whales. The Bering-Chukchi-Beaufort subpopulation has increased steadily over the last 30 yr (3.7% with 95% CI 2.8%–4.7% per year) with a 2011 abundance estimate of 16,892 individuals (95% CI: 15,704–18,928) (Givens *et al.* 2013). The 2002 abundance estimate for the Eastern Canada-West Greenland subpopulation was 6,344 (95% CI 3,119–12,906) (IWC 2009:23), but there is no IUCN assessment for this subpopulation. The species as a whole and the Bering-Chukchi-Beaufort Sea subpopulation are redlisted as Least Concern, but two subpopulations are still considered threatened by IUCN (Reilly *et al.* 2012*a*, *b*, *c*; Cetacean Specialist Group 1996*b*).

The Critically Endangered Svalbard-Barents Sea (Spitsbergen) subpopulation was probably the largest of the bowhead whale subpopulations immediately before commercial whaling began in the northeastern Atlantic in 1611. There has been no whaling on this subpopulation for over a century, and it has had little exposure to threats from fishing, shipping, and industrial activity. There is no current estimate of population size (hypothesized to be in the range of 50–120) and no clear or convincing evidence of substantial growth (Reilly *et al.* 2012*c*). Visual and acoustic observations over the past decade do suggest, however, that this subpopulation persists and may be increasing (Moore *et al.* 2012*b*, IWC 2014). Boertmann *et al.* (2015) reported a corrected abundance estimate of 102 whales (95% CI 32–329) from an August 2009 aerial survey of the Northeast Water Polynya off the northeastern coast of Greenland.

The Endangered Sea of Okhotsk subpopulation is thought to number only in the low hundreds compared to at least a few thousand prewhaling, and there is no clear evidence on trend (Reilly *et al.* 2012*b*). The subpopulation was subjected to intensive commercial whaling in the mid 1800s and at least sporadic whaling until 1913 (Ivashchenko and Clapham 2010). In addition, at least 145 were killed illegally by Soviet whalers in 1967 and 1968 (Ivashchenko and Clapham 2012). No additional deliberate kills are known, but at least one whale from this subpopulation is known to have died from entanglement in fishing gear (Brownell 1999). Oil and gas exploration activity is expanding rapidly in the Sea of Okhotsk and this brings risks of various kinds to bowheads (*e.g.*, habitat modification and degradation, noise disturbance, ship strikes).

As mentioned earlier, hunting of this species in Russia, Alaska (United States), and Greenland (Denmark) is managed within the IWC's aboriginal subsistence whaling framework. The hunting of bowhead whales became legal in Arctic Canada in 1991 and in Greenland in 2008. Although Canada is not a member of the IWC, it has agreed to report catches annually, thus enabling the IWC Scientific Committee to incorporate those catches in assessments and catch limits for the Eastern Canada–West Greenland stock as they apply to Greenland, which is a member. Aboriginal whaling is not currently viewed as a population-level threat to this species anywhere in its range.

North Atlantic Right Whale

North Atlantic right whales are functionally extinct in European waters from whaling which started 1,000 yr ago, and the most recent substantial whaling was in the first third of the 20th century on both sides of the North Atlantic (Reeves *et al.* 2007). Most, but not all (Brown *et al.* 2007), of the few European sightings in recent decades have been of individuals previously photo-identified off the U.S. and Canada (Jacobsen *et al.* 2004, Hamilton *et al.* 2007, 2009; Silva *et al.* 2012). The subpopulation in the western North Atlantic is considered Endangered but has been increasing since 2000. At the time of the last Red List assessment (Reilly *et al.* 2008*j*), the total population (all ages) was believed to number only 300–350, all of them in the western North Atlantic, and there was serious concern about the high rate of ongoing human-caused mortality from ship strikes and entanglement. The total estimated population size (all ages) in 2012 was somewhat more than 500 individuals (Pettis 2013) with an annual increase of 2.8% in the minimum number of live whales between 1990 and 2012.

North Pacific Right Whale

North Pacific right whales have not recovered after their extreme depletion by commercial whaling from 1835 through the 1840s (Josephson *et al.* 2008, Scarff 2001), continued hunting pressure throughout the rest of the 19th century and into the early 20th century, and illegal Soviet whaling on the small remnant population(s) in the 1960s (Brownell *et al.* 2001, Ivashchenko and Clapham 2012, Ivashchenko *et al.* 2013). The last commercial catch was by China in 1977 in the Yellow Sea (Brownell *et al.* 2001). There are thought to be two subpopulations, the eastern, described mostly from feeding areas in the Bering Sea and offshore in the Gulf of Alaska, and the western, feeding mainly in the Sea of Okhotsk and along the northern Kuriles and off Kamchatka. The species is redlisted as Endangered and the subpopulation in the eastern North Pacific as Critically Endangered because of its very small size and consequent vulnerability to extinction (Reilly *et al.* 2008*k*, *l*). The most recent accounting indicates that 765 right whales were taken by illegal Soviet whaling in the North Pacific[11] and this is thought to have removed the bulk of the population in the eastern North Pacific where they are now rarely seen. Genetic and photo-ID mark-recapture analyses each suggest there are only about 30 animals left in the eastern subpopulation, mainly observed in the southeastern Bering Sea and with a male bias to the population (Wade *et al.* 2011, LeDuc *et al.* 2012). There is very little current information on the species in the Gulf of Alaska. There is concern that increased ship traffic through Unimak Pass and in the Bering Sea will put eastern North Pacific right whales at greater risk of ship strikes.

The situation is better in the west, where data obtained during Japanese sighting surveys for minke whales in 1989, 1990, and 1992 led to an abundance estimate of 922 right whales in the Sea of Okhotsk (95% CI: 404–2,108) (Miyashita and Kato 1998, IWC 2001:26). However, the Red List documentation concluded that given the very wide confidence intervals and the lack of clear evidence of any recent increase in numbers, the lower end of the range of that abundance estimate (*i.e.*, about 400) should be used for assessment (Reilly *et al.* 2008*k*). Surveys for large whales in offshore waters east of Hokkaido (Japan) and the Kuril Islands from 1994 to 2013 resulted in 55 sightings of right whales (77 individuals) including ten female/calf pairs (Matsuoka *et al.* 2014), 10 sightings of right whales in five groups were reported in 2012 surveys southeast of the Kamchatka Peninsula and off the Kuril Islands (Sekiguchi *et al.* 2014) and there were 19 sightings of 31 whales in the Russian EEZ (mainly around the northern Kuril Islands, the southern Kamchatka Peninsula and the Commander Islands) between 2003 and 2014 (Ovsyanikova *et al*. 2015). Whales from this subpopulation are occasionally killed incidentally in coastal fishing operations around Japan and Russia (Burdin *et al*. 2004).[12] A highly publicized right whale entanglement in and subsequent escape from mussel mariculture gear occurred in South Korea in February 2015 (Kim *et al.* 2015). All data collected since 1992 in the western North Pacific, especially the Sea of Okhotsk, need to be analyzed for a new abundance estimate so that an assessment can be completed for this subpopulation.

Southern Right Whale

Southern right whales were hunted throughout the Southern Hemisphere by commercial whalers in the 18th and 19th centuries; as few as 400 individuals may have remained in the 1920s by which time the whaling had mostly ended (IWC 2001:24, IWC 2013*a*). Population growth occurred during the first half of the 20th century, but was set back between 1951/1952 and 1970/1971 when Soviet whaling expeditions killed over 3,300 southern right whales illegally (Tormosov *et al.* 1998). Over the past four decades, southern right whales in well-studied subpopulations off southern Africa, in the southwestern Atlantic (off Argentina and Brazil), and off south-central and southwestern Australia have shown relatively high rates of increase (IWC

[11]Yulia Vladimirovna Ivashchenko, 2363 16th Avenue S, Seattle, WA 98144, 11 February 2015.

[12]Japan Progress Reports to the IWC, https://iwc.int/scprogress.

2013*a*). The heavily exploited subpopulation around the Auckland Islands (New Zealand) has also increased since whaling stopped about 1970 (Carroll *et al.* 2011). The 1997 global estimate of southern right whales was about 7,500 (IWC 2001:23) and in 2009 it was about 13,600 (IWC 2013*a*). Although the species is now listed as Least Concern (Reilly *et al.* 2008*m*), at least one subpopulation is still in serious trouble. The Chile-Peru subpopulation in the southeastern Pacific is thought to include fewer than 50 mature individuals and thus is redlisted as Critically Endangered (Reilly *et al.* 2008*n*). The main concerns for this subpopulation are entanglement in fishing gear and coastal development (Galletti Vernazzani *et al*. 2014). Other subpopulations that have been at least tentatively identified as meriting consideration for threatened status are those off mainland New Zealand, although recent records indicate increasing occupancy of these waters by females with calves originally identified in the subantarctic calving grounds at the Auckland and Campbell Islands (Carroll *et al.* 2014), in the central South Atlantic around Tristan da Cunha, and around Crozet and Kerguelen Islands in the central Indian Ocean (IWC 2013*a*).

Pygmy Right Whale

The pygmy right whale is the smallest baleen whale with a maximum body length of 6.34 m in females and 6.1 m in males (Budylenko *et al.* 1973), compared to the 7 m length of a *newborn* Antarctic blue whale (Mackintosh and Wheeler 1929). It is also one of the least known species. Its phylogenetic relationships to other baleen whales are enigmatic and it has long been assigned to a monotypic family, Neobalaenidae. However, a recent analysis of morphological characters and molecular data concluded that the species possesses a number of synapomorphies with members of the fossil family Cetotheriidae (Fordyce and Marx 2012). Pygmy right whales are known from cold-temperate waters of the Southern Hemisphere, mainly between 19°S (in the Benguela Current) and 52°S (Kemper 2009), but most strandings and sightings have been in South Africa, New Zealand, and Australia (Kemper 2002). They apparently feed primarily on calanoid copepods (Budylenko *et al*. 1973) and their range overlaps that of sei whales, which also feed mainly on copepods. The species has never been a significant target of commercial whaling. All of what is known about these whales comes from stranded specimens, a few individuals killed during commercial whaling, and at-sea observations. No estimates of abundance are available. The pygmy right whale is classified as Data Deficient on the IUCN Red List (Reilly *et al.* 2008*o*).

Gray Whale

When assessed as a species, the gray whale is in the Least Concern category (Reilly *et al.* 2008*p*). Gray whales occurred in the North Atlantic until the late 1600s or early 1700s and perhaps somewhat longer (Mead and Mitchell 1984), but they are now extinct in this ocean basin. In the western and eastern North Pacific, gray whales were hunted commercially from the middle of the 19th century through the early 20th century, by which time both subpopulations had become seriously depleted. Following limited protection from commercial whaling in 1937 and full protection in 1946, the eastern North Pacific subpopulation recovered to a large degree. Estimates of abundance from the southbound migration for the period 2006/2007 to 2010/2011 ranged from 17,820 to 21,210 (IWC 2014:25) and were broadly consistent with previous estimates of between 15,000 and 22,000 (Laake *et al.* 2009, Punt and Wade 2010). This subpopulation may be large enough that the present-day carrying capacity is exceeded in years when delayed ice retreat or stochastic environmental processes reduce foraging opportunities in its subarctic and Arctic feeding grounds (Moore *et al.* 2003, Perryman *et al.* 2002, Reilly *et al.* 2008*p*). By contrast, the western subpopulation is redlisted as Critically Endangered (Reilly *et al.* 2008*q*) and has shown little sign of recovery from near-extirpation by commercial whaling which lasted until 1966 in Korea (Brownell and Chun 1977).

Subsistence whaling on the eastern stock of gray whales, which was widespread and at least locally intensive historically (Reeves 2002), continues off Chukotka, Russia, where under the current IWC catch limit 744 whales can be taken over the years 2013 through 2018 with no more than 140 to be taken in any one year (IWC 2014). Under a Russia-U.S. bilateral agreement, most of that quota is allocated to Russia. From 2004 to 2013 an average of 126 (111–143) whales was taken per year in this monitored hunt.[13] The possibility of a resumed legal hunt of gray whales by the Makah Tribe of Washington State is the subject of ongoing negotiations within the U.S. government (MMC 2014). A major point of concern is how to prevent whales from the Sakhalin feeding group (see below) or the Pacific Coast Feeding Group (PCFG) (again, see below) from being struck by the Makah whalers if and when their hunting resumes.

A small subpopulation of gray whales, numbering about 150, that feeds during the summer and autumn in Russian waters off northeastern Sakhalin Island and southeastern Kamchatka is redlisted as Critically Endangered (Reilly *et al.* 2008*q*). Extreme concern in recent years has centered on the possibility that oil and gas development at Sakhalin could degrade these whales' foraging habitat and cause direct disturbance or even physical harm to them. Deaths of gray whales in recent years in fishing gear around Japan and in Chinese waters have unquestionably slowed, or possibly entirely prevented, the return of gray whales to portions of the species' natural range that are now largely unoccupied. Such mortality demonstrates the vulnerability of the animals that hold the potential for restoring a regular gray whale migration along the coasts of eastern Asia. It was recently discovered that some of the gray whales found off Sakhalin in summer migrate eastward and southward to the wintering areas used by eastern gray whales (Mate *et al.* 2011, Weller *et al.* 2013*a*, IWC 2014). This would seem to indicate that the number of individuals using the species' historical migration route(s) and wintering area(s) along the Asian mainland is even smaller than previously thought. Continued intensive efforts are needed to protect (and further assess) gray whales in the western North Pacific.

The PCFG consists of a small group of whales that forages primarily between southeastern Alaska and northern California, *i.e.*, in an ecosystem distinct from that used by the larger migratory population that feeds mainly in the Bering and Chukchi Seas (Weller *et al.* 2013*b*). Photo-identification and genetic studies indicate that although the PCFG whales interbreed with the other eastern gray whales, they may still comprise a demographically distinct stock (Calambokidis *et al.* 2010, Frasier *et al.* 2011, Lang *et al.* 2011).

Subspecies and Subpopulations Not Yet Assessed

In this review, we have identified a number of baleen whale subspecies and subpopulations of conservation concern that have yet to be assessed for the IUCN Red List

[13]http://iwc.int/table_aboriginal.

or that may need to be changed from Data Deficient to some other Red List status. In our view, the following subspecies and subpopulations should be high priorities for IUCN Red List assessment as new data become available:

1. Small populations of "pygmy" type blue whales in numerous parts of the Southern Hemisphere need much more study of population structure, abundance, and trends; and, once sufficient information is available, Red List assessment.
2. The northern Indian Ocean blue whale (Arabian Sea) subspecies, heavily exploited by illegal Soviet whaling in the 1960s, is now of particular concern because of ongoing mortality from ship strikes and the likelihood of entanglement in fishing gear. The lack of information on current numbers is a significant impediment to assessment, but these whales otherwise rank high among global priorities for baleen whale conservation.
3. Gulf of California fin whales are considered discrete from other eastern North Pacific animals and, as occupants of a geographical cul-de-sac, they may be vulnerable to the impacts of climate change on their prey. East China Sea fin whales have long been recognized as a separate population but they have not been assessed by the IWC since they were intensively hunted by Japan up to the 1960s. Current threats are unknown but the most likely is ship strike as this subpopulation inhabits a region with extremely heavy vessel traffic, which is expected to grow rapidly as a result of changes in world trade patterns.
4. The resident subpopulation of Bryde's whale recently described in the northeastern Gulf of Mexico may be subject to the impacts of intensive oil and gas development and there is concern regarding ship strikes within their limited range.
5. The J-stock of common minke whales in the western North Pacific has long been recognized as a management stock by the IWC. Because it has been studied extensively, this subpopulation's distinctiveness, discreteness, and geographical distribution are reasonably well known. The combined impacts of past commercial whaling, "scientific" whaling, "bycatch," and illegal whaling on J-stock minke whales has resulted in their well-documented depletion.
6. Humpback whales in the North Atlantic Ocean constitute one of the most thoroughly studied basin-wide populations of baleen whales. However, the very small subpopulation in the eastern portion of the basin (migrating between the Cape Verde Islands in the winter and Iceland and Norway in the summer) has yet to be assessed. Any entanglements or ship strikes could have a negative impact on this population. Also, the possibility of a third North Atlantic breeding area in the southeastern Caribbean requires more investigation.
7. Humpback whales in the western North Pacific were heavily exploited by Japan until the 1960s. This subpopulation is one of the smallest in the North Pacific and is therefore of particular concern because of ongoing entanglement in fishing gear and possibly ship strikes in one of the world's fastest-growing marine traffic areas.
8. The central South Atlantic (around Tristan da Cunha) and southwestern and central Indian Ocean subpopulations of southern right whales are small, remote, and little known.
9. The gray whale, certainly one of the most intensively studied baleen whale species, is considered Least Concern at the species level while the western subpopulation is listed as Critically Endangered. The IWC Scientific Committee is carrying out an in-depth investigation of the population structure and conservation status of

North Pacific gray whales (IWC 2014). It will be important for the results of that investigation to be used in a Red List reassessment of gray whales in the western North Pacific as soon as feasible.

Based on the above list, we believe it should be possible to move forward without delay to assess the following subpopulations: J-stock common minke whales, Gulf of Mexico Bryde's whales, and western North Pacific humpback whales.

Summary and Conclusions

Among the baleen whales, the right whales remain the group of greatest conservation concern at the species level. Both the North Atlantic and North Pacific right whales are endangered. In the eastern North Atlantic, right whales were effectively extirpated (by whaling) by the early 20th century, and the principal ongoing threats to right whales in the western North Atlantic are immediate and well-documented: entanglement and ship strike. In the North Pacific, there are probably still hundreds of right whales on the western side but only a few tens on the eastern side, where the prognosis for recovery is bleak. North Pacific right whales presumably face the same threats as their North Atlantic congeners (entanglement and ship strike) although it is not certain to what degree. Further research is needed to understand more about their distribution, movements, numbers, and areas where they are most vulnerable to these and other threats (*e.g.*, future offshore oil and gas development and increased northern ship traffic).

While southern right whales are showing strong evidence of recovery in much of their former range, their status in several areas is still of great concern. The very small size of the Chile-Peru subpopulation puts it at high risk from entanglement and ship strike. Very few right whales are present today around the New Zealand mainland, but at least there are encouraging signs that animals from the Auckland Islands are moving in to reestablish the species in that area. Emergent problems, such as the growing attacks by kelp gulls on right whales in Argentina due to increases in the local human population and fishing (Thomas *et al.* 2013), are reminders that the process of recovery can be impeded by unpredictable and unlikely developments even for a population that has been growing steadily for more than 40 years.

Among the rorquals, Mediterranean fin whales have been identified for concern because of the cumulative impacts of human activities in that semienclosed basin. Similar concerns, plus those related to oil and gas development, are likely to apply to the very small population of Bryde's whales in the northern Gulf of Mexico (Rosel and Wilcox 2014). Antarctic blue whales were reduced to such a degree (less than 1%) by commercial whaling in the 20th century that their recovery, even in the absence of whaling, has been very slow. Blue whales have been effectively extirpated from east Asian waters (off Japan) where they were present in good numbers before commercial whaling started about 1900. Other blue whale populations (*e.g.*, northern Indian Ocean (Arabian Sea) and Chile-Peru) are being affected by ship strikes but the population-level consequences of the mortality remain difficult to assess.

Despite encouraging resurgences in most of their range, humpback whales are still not secure in a few areas. In particular, the small population in the Arabian Sea breeds out of phase with more southerly populations and is at considerable risk from entanglement in fishing gear and perhaps ship strikes. Numerous other humpback populations experience substantial mortality from ship strikes and entanglement. In many such cases the population is still increasing, but in other cases the population-level consequences are uncertain, similar to the situation for the blue whale populations mentioned above. As whale numbers grow, the incidence of ship strikes and entanglements is likely to increase even if vessel traffic and fishing activity in their habitat remains unchanged. It is difficult to separate, measure, and assess the factors most responsible for the high rates of mortality and injury, but there is reason for concern that in some regions at least, human activities are limiting or even preventing population recovery. In this regard, one area of concern is the western North Pacific humpback subpopulation which is subject to bycatch and inhabits a region with high vessel traffic.

In addition to the longstanding threat of entanglement in fishing gear (Clapham *et al.* 1999), the problem of ship strikes has come to be recognized as the other clearest and most direct threat to small baleen whale populations. It will get worse as international commerce continues to expand and as maritime traffic moves into areas formerly difficult or impossible to navigate because of sea ice. Biologically rich straits such as the Bering Strait and the passes through the Aleutian Islands, other places where major shipping routes come near shore, such as the southern tip of Sri Lanka, the waters off China and South Africa, and heavily used ports such as those on the eastern, Gulf of Mexico, and western seaboards of North America, are conflict zones where the ship strike menace is particularly in evidence.

Oil and gas development activities in the Arctic represent an emerging threat to bowhead whales, especially in their feeding range. This is especially worrisome for the small populations in the Sea of Okhotsk and around Svalbard-East Greenland and in the Barents Sea. Oil and gas development on the Sakhalin shelf is of great concern for the small population of gray whales that relies on this area as a summer feeding ground. It is difficult to see how gray whales will be able to expand their effective range in the coastal waters of China, Korea, and Japan, where they were all but extirpated by whaling in the 20th century, unless their feeding habitat in the Sea of Okhotsk and off southern Kamchatka is maintained in a healthy condition and the threats of entanglement and ship-strike are rigorously managed along their migration route(s) and at their wintering grounds.

Chemical contaminants are a general, longstanding concern, but they are not known to be having population-level impacts on baleen whales. This could, however, simply reflect the difficulty of documenting and measuring such impacts. The actual long-term effects of increasing anthropogenic noise are unknown, but in addition to the need to manage the acute impacts of noise, there is growing concern about the potentially serious impacts of chronic stress from noise exposure (Rolland *et al.* 2012), the masking of salient acoustic signals (Clark *et al.* 2009), and the possible displacement of animals from critical habitat (Moore and Huntington 2008). Efforts to assess the cumulative effects of the range of anthropogenic and natural stressors on marine mammals are challenging and require long-term commitment (National Research Council 2005, Schick *et al.* 2013, King *et al.* 2015).

Climate change is already affecting aspects of baleen whale ecology and phenology. For example, bowhead whale populations formerly separated by sea ice in the summer have begun to mingle more frequently in the Northwest Passage and species such as gray, humpback, and fin whales are increasingly observed in high Arctic waters. Annual changes in the distribution of rare animals such as North Atlantic right whales are often hypothesized to be related to changing climatic or oceanic conditions but we often lack the data to draw firm conclusions. Similarly, there are serious concerns that cul-de-sac populations such as the humpback whales and blue whales in the Arabian Sea, bowhead whales in the Sea of Okhotsk, and fin whales in the

Table 3. Baleen whales: species, subspecies, and populations of greatest concern based on this review.

Species/subspecies/subpopulation	Current situation including Red List status	Primary conservation requirements
Bowhead whale (Sea of Okhotsk subpopulation)	Endangered: population size thought to be in the low to mid 100s, only known immediate lethal threat is entanglement	Document distribution and abundance; implement measures to mitigate disturbance from oil/gas activity including seismic surveys
Bowhead whale (Svalbard-Barents Sea subpopulation)	Critically Endangered: population size unknown but few sightings, no immediate lethal threats known	Document distribution and abundance; monitor potential for increasing disturbance from oil/gas activity including seismic surveys
Southern right whale (Chile-Peru/SE Pacific subpopulation)	Critically Endangered: current population likely <50, most immediate lethal threat entanglement and they are at risk of ship strikes in much of their range	Characterize and mitigate bycatch risk (from coastal artisanal and commercial fisheries) and risk of ship strikes (ship traffic is heavy in some parts of range)
North Atlantic right whale	Endangered: total population ~500, extirpated from eastern portion of range, mortality and injury from entanglements and ship strikes well documented in United States and Canada	Continued and strengthened measures to reduce ship strike and entanglement risks
North Pacific right whale (western subpopulation)	Not assessed separately but species is Endangered: hundreds in the Sea of Okhotsk and Kamchatka/Kuriles portion of range but still far below level of precommercial whaling	Document distribution and abundance; evaluate risk of ship strikes, entanglements, and disturbance from oil/gas activity including seismic surveys
North Pacific right whale (eastern subpopulation)	Critically Endangered: current population estimated at around 30, considerable risk of ship strikes suspected but not well documented	Document year-round distribution and evaluate risk of ship strikes from increased ship traffic and entanglements
Common minke whale (western North Pacific "J-Stock")	Not assessed: Autumn-breeding stock centered in Sea of Japan, numbers in thousands, substantial "bycatch" (100s/yr) in Japan, Korea, and China (but not reported)	Characterize and mitigate "bycatch" risk in Japan, Korea, and China; eliminate illegal whaling

(Continued)

Table 3. *(Continued)*

Species/subspecies/subpopulation	Current situation including Red List status	Primary conservation requirements
Antarctic blue whale	Critically Endangered: 1997 population (2,280) around 1% of pre-exploitation level (239,000), but increasing, no immediate lethal threats known	Document abundance and distribution; continue protection from whaling
Pygmy blue whale populations (*e.g.*, East South Africa, Madagascar to Kerguelen, South Atlantic, Chile-Peru, New Zealand, and Southwest Pacific: New Caledonia, and Solomon Islands)	Subspecies Data Deficient and all subpopulations not assessed: all presumed to be less than 1,000.	Document subpopulation characteristics and threats, especially entanglement, ship strikes and oil and gas development
Northern Indian Ocean blue whale	Not assessed: small distinct population mainly in northern Indian Ocean between Gulf of Aden and South Asian subcontinent, breeds 6 mo out of phase with populations in the Southern Hemisphere	Document abundance and year-round distribution; implement measures required to reduce ship strike risk
Fin whale (Mediterranean subpopulation)	Vulnerable: population size <5,000 mature individuals, declining	Mitigate risks from ship strike, entanglement, ship and other noise
Bryde's whale (northeastern Gulf of Mexico subpopulation)	Not assessed: small distinct subpopulation resident year-round in the northeastern Gulf of Mexico	Document subpopulation characteristics and threats and mitigate risks from intensive oil and gas development and potential ship strikes
Humpback whale (Arabian Sea subpopulation)	Endangered: abundance estimate in Oman 82 (95% CI = 60–111), breeds 6 mo out of phase with populations to south	Document abundance and year-round distribution; implement measures to reduce entanglement (and ship strike) risk
Gray whale (western subpopulation)	Critically Endangered: gray whales at Sakhalin Island comprise a discrete subpopulation of about 150 animals or less; at least part of this subpopulation migrates annually to west coast of North America including Mexican breeding lagoons	Continue and strengthen measures to mitigate disturbance from oil and gas activity, ship and other noise, and reduce bycatch risk in set nets in Japan and China

Mediterranean Sea, East China Sea, and Gulf of California are habitat-limited and will suffer as ocean temperatures rise and their prey base is altered.

The population-level consequences of ongoing environmental changes stemming from climate change and ocean acidification, *e.g.*, in ecosystem structure, prey availability, and access to seasonally occupied habitat, remain uncertain and difficult to characterize. Intensive research, including the development and application of new methods, is needed to gain a better understanding of those consequences. At the same time, there is a pressing need for more "baseline" data on the historical and present-day ranges, seasonal movements, and habitat requirements of baleen whales against which to assess impacts and decide where mitigation is most warranted. The large differences among countries in their resources available to support scientific assessment and management action, even when it comes to tackling the most basic threats of entanglement and ship strike, mean that regional or broader international cooperation is needed. Such cooperation may be especially urgent when endemic or highly localized populations are under threat.

Future conservation of baleen whales must focus at the population level to be meaningful. This requires a much better understanding of the population structure and abundance of all species so that we can better assess and manage the population-level impacts of the threats they face. Such research is bound to add to the list of species, subspecies, and subpopulations of greatest concern (Table 3).

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Supporting Information

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Table S1. Baleen whales species, subspecies, and subpopulations: Current situation, primary and potential, or emerging threats.