Chapter 4
Baleen Whale Migration

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> *Paikea is an ancestor of many* [Māori] *iwi (tribal groups) of the eastern seaboard of Aotearoa New Zealand. The Paikea story is known in other parts of the Pacific and provides an explanation for how this particular ancestor reached Aotearoa from the ancestral and spiritual home-land of Hawaiki. There are several versions of the story, but it is commonly accepted that he was the sole survivor of a marine disaster and through his endeavors reached shore at a place called Ahuahu. This was achieved through the mobilization of his marine ancestors, his family of whales, who helped him reach Aotearoa. Paikea is described as riding on the back of a whale, or transforming into a whale, and is referred to accordingly as he tahito, he tipua, he taniwha, he tohorā, he tangata, he tekoteko—an ancient being, an extraordinary being, a denizen of the deep, a whale, a man, a sentinel for his people. Paikea is also the Māori name for southern humpback whales [i.e. Oceania population of Megaptera novaeangliae].*
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> *The Paikea narrative underpins a certain type of relationship with whales, one of kaitiakitanga—care or stewardship. This is conceptualized in whakapapa [i.e. genealogy] terms, whereby whales are identified as ancestors and kin. The kaitiaki [i.e. guardian] relationship underpins voyaging knowledge contained in oral histories. Whales guide waka (canoes/vessels) to land, through dangerous seas and channels, and are called upon to smooth rough waters for safe passage. Ocean-going waka hourua are double-hulled to replicate the physical qualities of a pair of whales cresting waves in tandem.*
>
> *Tere tohorā, tere tangata—where whales journey, people follow—is a whakataukī (proverb) that encapsulates the essence of this synergy.*
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> Billie Lythberg and Wayne Ngata (Te Aitanga a Hauiti), New Histories of Pacific Whaling, Rachel Carson Center Perspectives, No. 5, pp. 105–106, 2019

Abstract Baleen whale migration emerges as a foundational theme of cetacean behavioral ecology and the relationships that bind humans and whales together. From facilitating the culmination of the great human migration many centuries ago, to their roles as ecosystem service providers, baleen whales have influenced the path of human history. With a focus on modern technologically enabled insights, we provide an overview of what scientists currently know about the spatial and temporal distribution of baleen whales and their migratory behaviors. Although a coarse model of seasonally paced north–south migration generally applies, a deeper analysis reveals the remarkable diversity of baleen whale migrations. Some species, including gray whales (*Eschrichtius robustus*), migrate relatively close to shore; others, including humpback whales (*Megaptera novaeangliae*), tend to migrate across ocean basins. Some species, including Bryde's whales (*Balaenoptera edeni*), appear to largely reside in middle to low-latitude ecosystems, relatively removed from cold, high-latitude water. In contrast, bowhead whales (*Balaena mysticetus*) remain within Arctic ecosystems all year, and others, including Omura's whales (*Balaenoptera* *omurai*), may not migrate at all. The scientific focus to date has largely been on population-specific studies of where whales go, what their behaviors are, and when they undertake their migrations. Thus, there remains much to be learned, particularly regarding why baleen whales migrate and how they navigate during their long-distance migrations. Technological innovations such as satellite tags and passive acoustics have revolutionized our understanding of baleen whale behavioral ecology and ethology, and technology will continue to play a critical role in advancing the science of baleen whale migration.

Keywords Baleen whale · Migration · Telemetry · Satellite tracking · Passive acoustics · Migratory behavior · Movement behavior · Acoustic behavior · Orientation · Navigation

4.1 Introduction

The powerful and ancient synergy between Paikea, the migratory humpback whales (*Megaptera novaeangliae*) of the Pacific, and Polynesian tūpuna/kūpuna/ancestors* continues to tie humans and whales together. In many places, indigenous rights to stranded whales are protected by law, and local communities like Kaikōura, in Aotearoa New Zealand, and Vava'u, in Tonga, benefit from whale watching activities that attract tens of thousands of visitors every year. Perhaps the most significant connection between whales and humans is the role whales play in removing carbon from the atmosphere. By spreading nutrients around, whales increase oceanic primary production (e.g., Lavery et al. 2014), and by virtue of their large body sizes and long life spans, growing whale populations act as a net sink in the global carbon cycle, locking away tons of carbon for extended periods of time (e.g., Pershing et al. 2010). As another whakataukī goes: *Ko ahau te tohorā, te tohorā ko ahau/I am the whale, and the whale is me.*

Emergent themes in the whale–human nexus include guardianship, sense of place, observation, connectivity, and unity. Yet, perhaps the most salient theme is migration. For example, 'People of the Whales', Iñupiat of Arctic Alaska, have accumulated vast knowledge of bowhead whale migrations over centuries of observation, and this knowledge is fundamental to Iñupiaq life and culture (Sakakibara 2017). Elsewhere, Paikea, an ancestor of many Māori, was guided by Paikea, the humpback whale, during the great human migration from Hawaiki to Aotearoa. Centuries old oral traditions underscore the more recent scientific observation that Aotearoa New Zealand is a global hotspot for whales and whale strandings at the intersection of the migratory corridors utilized by at least five different baleen whale populations. As the ancestors knew, a stranded migrating whale provides sacred resources to its descendants, while a live whale grows the ocean's bounty. Modern economies and local job markets where whale watching has a significant presence are paced by the phenology (seasonal timing) of great whale migrations. The epic migrations of baleen whales have connected us, supported us, protected us, and unified us for centuries.

From all perspectives, baleen whale migrations are remarkable. Generally defined, migration is a natural phenomenon that involves movement between different locations for specific purposes such as feeding or reproduction (Dingle and Drake 2007). Migration facilitates ecosystem services and the sustainability of marine resources, including small fish and krill (Roman and McCarthy 2010). Although many different animals migrate, migratory behaviors are diverse, and baleen whales are no exception.

This chapter provides a high-level overview, presented in two parts, of what is currently known about baleen whale migration. Part one considers the migratory patterns of baleen whales. Several central questions serve as a framework for this section, including: Why do baleen whales migrate? Where do baleen whales go? How fast do baleen whales swim? How long do the migrations last? When do the migrations occur? What marine ecosystems and environments do whales migrate between? Part two focuses on the impact of technology on our understandings of baleen whale migrations. We highlight some of the technological advances and innovations that have helped steer the scientific community toward potential answers to the central questions of marine megafauna movement ecology. The central questions we address in this section include: How has baleen whale recovery and conservation been facilitated by scientific insights? How might baleen whales orient and navigate during long-distance migration? How have baleen whale hotspots been identified? We conclude the chapter with a brief look at the horizon.

4.2 Part I: Migratory Patterns of Baleen Whales

Whale migrations stand out as some of the most incredible behaviors in nature. Most baleen, and some toothed, whales migrate. These journeys include the longest known migrations of any mammal (Fig. 4.1). For example, individual whales, including the gray whale (*Eschrichtius robustus*) 'Varvara' (Mate et al. 2015) and the humpback whale 'AHWC #2950' (Robbins et al. 2011), completed round-trip annual migrations of approximately 18,000–21,000 km. Although many school-age children know that blue whales (*Balaenoptera musculus*) are the largest animals ever to have lived, fewer likely know that despite their unprecedented size blue whales are capable of swimming at ~6 km h^{-1} over distances greater than 6000 km during a ~6-week-long migration across an open ocean (Hucke-Gaete et al. 2018). Although they have a more restricted geographic range in comparison, individual bowhead whales (*Balaena mysticetus*) swim more than 10,000 km in a single year, the equivalent of one-quarter the way around the world (Fortune et al. 2020a).

Despite many nuances and unknowns, a generalized pattern of migratory behavior has been recognized over the past century. Much of our early knowledge of migrations of pelagic species arose from reports of commercial whaleships and the extensive discovery marking program (Kellogg 1929; Mackintosh and Wheeler 1929; Mackintosh 1972). Arguably, the patterns described may have been more reflective of the seasonal migration of whalers from hemisphere to hemisphere, rather than that of whales. The discovery marking program, in which labeled steel cylinders were

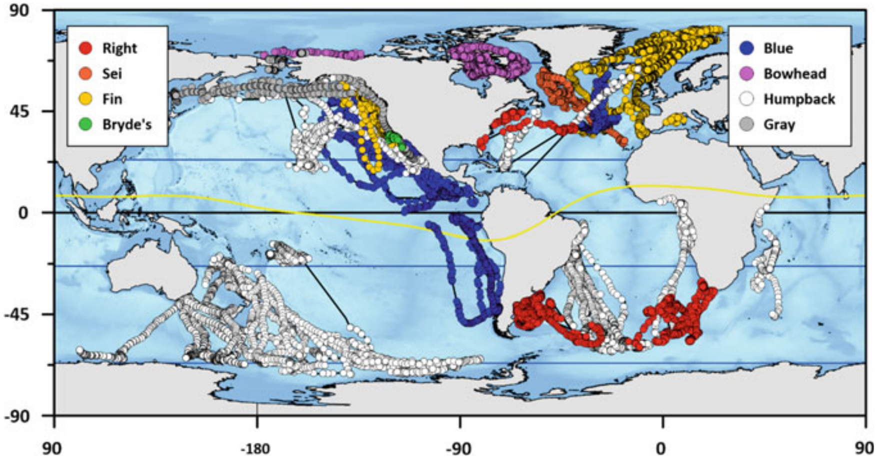

Fig. 4.1 Global compilation of some published baleen whale satellite tracking datasets (Williamson 1998; Zerbini et al. 2006; Hauser et al. 2010; Block et al. 2011; Horton et al. 2011; Silva et al. 2013; Irvine et al. 2014; Kennedy et al. 2014; Prieto et al. 2014; Garrigue et al. 2015; Kennedy et al. 2015; Mate et al. 2015; Cerchio et al. 2016; Zerbini et al. 2016; Horton et al. 2017; Andrews-Goff et al. 2018; Hucke-Gaete et al. 2018; Riekkola et al. 2018; Fortune et al. 2020a; Horton et al. 2020; Irvine et al. 2020; Lydersen et al. 2020; Palacios and Mate 2020). Blue lines show the position of the Tropics and Polar Circles. Thicker black line shows the geographic equator. Yellow curve shows the position of the magnetic equator in 2015. Circles represent platform transmitting terminal (PTT) whale location estimates and are colored by taxonomic group as indicated in the legends

fired into free-ranging whales and later recovered when carcasses were processed by whaleships, provided endpoints for the movements of marked whales that showed evidence of some very long-distance migratory movements (Brown 1954). This generalized and overly simplistic pattern of migration includes annual movements between foraging areas in polar or subpolar regions and breeding/calving habitats in tropical environments (Dawbin 1966; Norris 1967). For most baleen whales, the annual migration to higher-latitude environments occurs in spring and summer for feeding, while return migrations to lower-latitude environments typically occur in autumn and winter for breeding and calving.

This generalized pattern of baleen whale migration has variation within it. For example, some species, including blue whales and bowhead whales, likely feed throughout their annual range, whereas humpback whales and gray whales concentrate their feeding in specific higher-latitude areas at specific times of year. Migrations associated with mating and calving are similarly complex. While bowhead whales calve in the spring at higher latitudes in frigid waters (Nerini et al. 1984), gray, humpback, and right whales calve during winter in warmer and shallower waters of coastal lower-latitude environments (Lockyer 1984). Although there is an overarching pattern of baleen whale migratory behavior, it is not universal. Documenting and explaining the diversity in migratory behavior remain important goals of baleen whale research.

Another goal of current research on baleen whales is understanding the drivers and motivations of the long-distance migratory behaviors exhibited by most species. A number of hypotheses have been posed during recent decades, including (1) calf thermoregulation (Norris 1967, but see Sumich 2021); (2) energy optimization (Brodie 1975); (3) calf survivorship in calm water (Whitehead and Moore 1982); (4) vestigial behavior (Evans 1987); (5) resource tracking (Payne 1994); (6) predator avoidance (Corkeron and Connor 1999; Connor and Corkeron 2001); (7) breeding and calving in more equable environments (Clapham 2001); and (8) skin maintenance (Pitman et al. 2020). When considering this prolonged scientific debate, and the evidence both for and against the various hypotheses, one thing becomes clear: It is unreasonable to expect one hypothesis to accurately explain the diversity of baleen whale migratory behaviors.

For example, the recognition of non-migratory behaviors in some humpback (e.g., Straley 1990), fin (Geijer et al. 2016), Bryde's (Best 2001) and Omura's whales (Cerchio and Yamada 2018) suggests that traditional models are too simplistic (Geijer et al. 2016). Perhaps some species migrate with resultant benefits of reduced risk of predation and increased calf survivorship (Corkeron and Connor 1999; Connor and Corkeron 2001). The role humpback whale escorts play in actively protecting migrating mother-calf pairs from killer whale (*Orcinus orca*) and white shark (*Carcharodon carcharias*) predation is compelling (Pitman et al. 2015). Yet, it is just as reasonable to suspect that others likely migrate due to potentially harmful diatomaceous coatings of the skin (Durban and Pitman 2012; Pitman et al. 2020) or some combination of factors.

Although we do not yet know why many baleen whales migrate, technological advances have enabled a rapid growth in our knowledge of when and where whales are located. In the following subsections, we summarize representative knowledge, including the spatial patterning and timing of baleen whale migrations at the species level. Population specific examples are included to demonstrate the diversity of baleen whale migratory behaviors.

*4.2.1 Bowhead Whale (*Balaena mysticetus*)*

The migratory patterns of bowhead whales, the only baleen whale endemic to Arctic waters, vary among populations and are influenced by seasonal patterns of sea ice cover (Ferguson et al. 2010). Sea of Okhotsk (off Eastern Russia) bowhead whales are believed to be resident to that region and may occupy different subregions at different times of the year without undertaking long migrations (Shpak and Paramonov 2018). However, other bowhead whale populations maintain a characteristic meridional movement pattern from more southern environments into more northern environments in late spring and summer, followed by a reverse migration in autumn (Fig. 4.2).

Bowhead whales in the Western Arctic (the Bering-Chukchi-Beaufort population, Chap. 12) overwinter in the Northern Bering Sea (Alaska, USA) and migrate

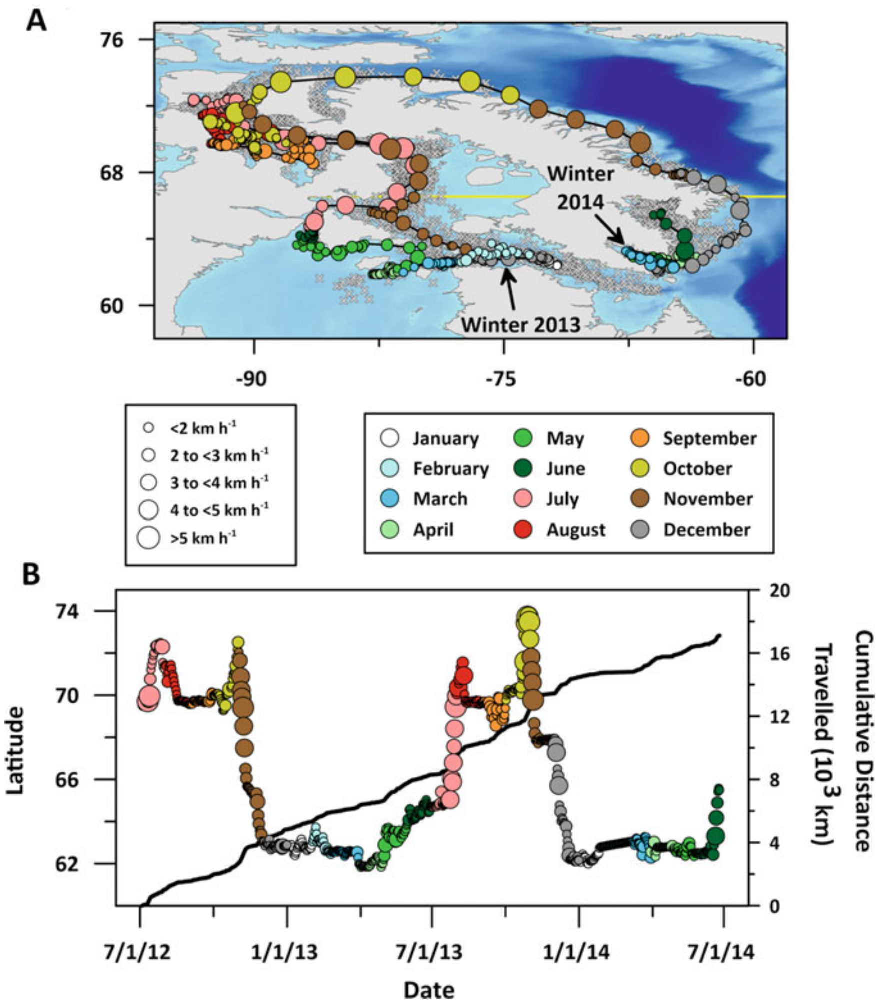

Fig. 4.2 Map (**A**) and time-series plot (**B**) of the multi-annual migrations of a bowhead whale, PTT#114495 (Fortune et al. 2020a), over a 723 day period starting in July 2013 and ending in June 2014. Panel **A** presents a plate carrée projection of PTT#114495's satellite-monitored migrations near Baffin Island, Eastern Canadian Arctic (circles; size represents swimming velocity and color represents month, as indicated in the legends). Gray crosses show every tenth Argos location estimates for 59 different bowhead whales tracked by Fortune and others (2020a). Blue-scale marine base map depicts bathymetry, and the Arctic Circle is represented by the yellow line. Panel **B** presents Julian calendar timing of PTT #114495's movements with respect to latitude (symbols as in **A**) and cumulative distance traveled (black line plot)

northward through the Chukchi Sea during spring into summer feeding grounds in the Canadian Beaufort Sea before returning westward toward Chukotka (Russia) in the late fall and then south into the Bering Sea in early winter. The spring migration occurs in stages, with whales of different age, sex, and reproductive status migrating at slightly different times. For instance, mothers with calves tend to be the last to move north in the spring (George et al. 2004). This migratory pattern has been confirmed by multiple lines of evidence, including satellite tracking (e.g., Quakenbush et al. 2013; Citta et al. 2015, 2018), passive acoustic studies (Moore et al. 1989, 2010; Clark et al. 2015), photographic identification and aerial surveys (e.g., Rugh et al. 2008; Clarke et al. 2016), geographic analysis of whale ship log books (e.g., Smith et al. 2012) and indigenous knowledge (e.g., Noongwook et al. 2007). Likewise, bowhead whales from the Eastern Canada-Western Greenland population exhibit similar north–south migratory patterns (Heide-Jørgensen et al. 2006, 2012, Fortune et al. 2020a; Fig. 4.2). In contrast, the Spitsbergen population of bowhead whales appears to have an opposite migratory pattern, reflecting the diversity of migratory behaviors in different populations. Spitsbergen bowheads tend to disperse to the south and east during spring and summer, while returning northward into the ice in autumn and winter (Lydersen et al. 2012; Kovacs et al. 2020).

Bowhead whales are believed to feed throughout their range, with breeding and calving occurring in spring (Nerini et al. 1984; Fortune et al. 2020b, c) rather than winter. Thus, bowhead whale migrations appear to be strongly associated with the spatiotemporal availability of food and the distribution of sea ice (Kovacs et al. 2020; Citta et al. 2021; Heide-Jørgensen et al. 2021). Bowhead whale migratory swimming velocities typically range between 3 and 6 km h^{-1}, over one-way migratory distances of several hundred kilometers to more than 3000 km migrations that can last as long as 9 weeks.

Although much is known about bowhead whale migrations, the application of passive acoustic technologies has continued to expand our knowledge. For example, a recorder placed in northern Fram Strait beginning in 2008 led to the discovery of a wintering, and likely breeding, ground for the critically endangered Spitsbergen population of bowhead whales (Stafford et al. 2012, 2018). This is a region that is remote, covered in sea ice most of the year and largely inaccessible as a consequence. The discovery of this hotspot has since led to an interdisciplinary program combining helicopter-based aerial surveys and satellite tagging that has yielded information on a population estimate and seasonal movements of these bowhead whales (Vacquié-Garcia et al. 2017; Kovacs et al. 2020).

*4.2.2 Right Whale (***Eubalaena australis***;* **E. glacialis***;* **E. japonica***)*

North Atlantic (*Eubalaena glacialis*), North Pacific (*E. japonica*), and Southern right whale (*E. australis*) movements are diverse. Some right whale populations adhere to the generalized baleen whale migratory pattern of predominantly north–south (i.e., meridional) movements between lower-latitude calving areas and higher-latitude feeding areas (e.g., Clapham et al. 2004; Munger et al. 2008; Mate et al. 2011). In contrast, some North Atlantic right whales follow a condition-dependent partial migration within neritic ecosystems off North America (Gowan et al. 2019).

In the Southwest South Atlantic, some southern right whales depart shallow water calving grounds and swim north rather than south (Zerbini et al. 2018). Yet, other southern right whales depart the continental shelf in predominantly zonal (i.e., east–west) long-distance migrations (e.g., Zerbini et al. 2018; Mackay et al. 2020), showing a remarkable diversity in movement behaviors. North Atlantic right whale migrations reinforce this complexity. In this species, mating and calving occur in different marine environments at different times of the year, suggesting a likely spatiotemporal division within a right whale population depending on reproductive status (Cole et al. 2013).

Intensive long-term visual surveys (e.g., Charlton et al. 2019), including photographic identification, passive acoustic monitoring studies (e.g., Davis et al. 2017), genetic studies (e.g., Carroll et al. 2020), and satellite tagging research (Zerbini et al. 2018; Mackay et al. 2020) have all made important contributions to unraveling the movements and migratory behaviors of endangered right whales. For example, passive acoustic monitoring identified critical habitat for the North Pacific right whale (Mellinger et al. 2004; Munger et al. 2008; Širović et al. 2015) and, as with the Spitsbergen bowhead, has directed broader research programs in photo and genetic identification of individual whales (Wade et al. 2011). Similarly, satellite tracking has demonstrated that right whales can migrate several thousand kilometers over a period of weeks while maintaining overall migratory swimming speeds between 3.5 and 6.5 km h^{-1} (Mate et al. 1997, 2011). The timing of many right whale migrations, revealed by both satellite tagging and passive acoustic monitoring, follows the general seasonal pattern of equatorward movement in autumn and poleward movement in spring (Mate et al. 2011; Davis et al. 2017).

*4.2.3 Pygmy Right Whale (***Caperea marginata***)*

Extremely little is known about the biology and movement ecology of pygmy right whales. They are believed to be a temperate to circumpolar Southern Hemisphere species capable of performing seasonal migrations between oceanic and neritic environments (Kemper 2009), not unlike their larger namesake.

*4.2.4 Blue Whale (***Balaenoptera musculus***)*

Many blue whales adhere to the stereotypical baleen whale pattern of predominantly north–south, long-distance migrations between seasonal feeding and breeding grounds (Fig. 4.3). A diverse suite of methods, including satellite tagging (e.g., Mate et al. 1999; Hucke-Gaete et al. 2018; Abrahms et al. 2019a, b), passive acoustics (Stafford et al. 1999a; b; Stafford 2003; Buchan et al. 2014; Oestreich et al. 2020), photographic identification studies (e.g., Calambokidis et al. 1990; Sears et al. 1990) as well as geographic analysis of whaling vessel log books (e.g., Reeves et al. 2004), has produced similar information on migratory patterns.

The locations of, and movements between, blue whale seasonal habitats vary regionally. Antarctic blue whales (*B. m. intermedia*) typically summer near the Antarctic continent, south of 60 S, followed by migrations to productive temperate waters during the winter. However, migratory destinations are generally not well known (Branch et al. 2007). Year-round occurrence of Antarctic blue whales in high-latitude environments (Širović et al. 2009; Thomisch et al. 2016) suggests that some blue whales may not migrate.

In contrast, pygmy blue whales (*B. m. brevicauda*) typically do not migrate to Antarctic waters in the summer, but in some regions migrate between temperate and tropical habitats (Double et al. 2014). Satellite tagging of pygmy blue whales off Southwest Australia suggests that their movement behaviors, including long-distance migrations, are not unlike those of other blue whales (Möller et al. 2020).

Chilean blue whales (*B. m.* subsp.) are known to migrate from summering habitats off the coast of Chile toward lower-latitude habitats in the Equatorial Pacific Ocean, close to the Galapagos Islands (Buchan et al. 2015; Hucke-Gaete et al. 2018). In the North Pacific, blue whale feeding grounds tend to be in the middle to higher latitudes, often less than 250 km from the coast, where upwelling can fuel seasonal blooms in primary production (e.g., Burtenshaw et al. 2004; Branch et al. 2007, Abrahms et al. 2019a).

Blue whale breeding and calving areas are believed to be in tropical marine environments, including offshore biological hotspots such as the Costa Rica Dome (Cromwell 1958) and the Galapagos Islands (Palacios 1999; Hucke-Gaete et al. 2018). Blue whale migratory swimming velocities range between ~2 and ~7 km h^{-1}, with some of the longest migrations exceeding 6000 km traveled over >6 weeks of essentially continuous directional swimming (Hucke-Gaete et al. 2018) during autumn and spring (Fig. 4.2).

Passive acoustic monitoring has been particularly instrumental in understanding seasonal changes in the global distribution of blue whales and from this, inferring migratory pathways and timing (Chap. 9). Blue whales produce sequences of sounds (songs) that are stereotyped and remain relatively unchanged over decades. Because their songs are often distinct, they have been used to define ‘acoustic populations’ of blue whales and their geographic ranges. For example, in the Eastern North Pacific, the complementary seasonal acoustic detection of blue whale songs has shown that Eastern North Pacific blue whales range from the Gulf of Alaska to the Equator, while Southeastern Pacific blue whales move northward from Chilean Patagonia to the Equator (Stafford et al. 1999a, b; Stafford 2003; Buchan et al. 2014). Similarly, Antarctic blue whale song detections suggest that these whales migrate northward from the ice edge to the tropics in three ocean basins (Stafford et al. 2004; Samaran et al. 2019).

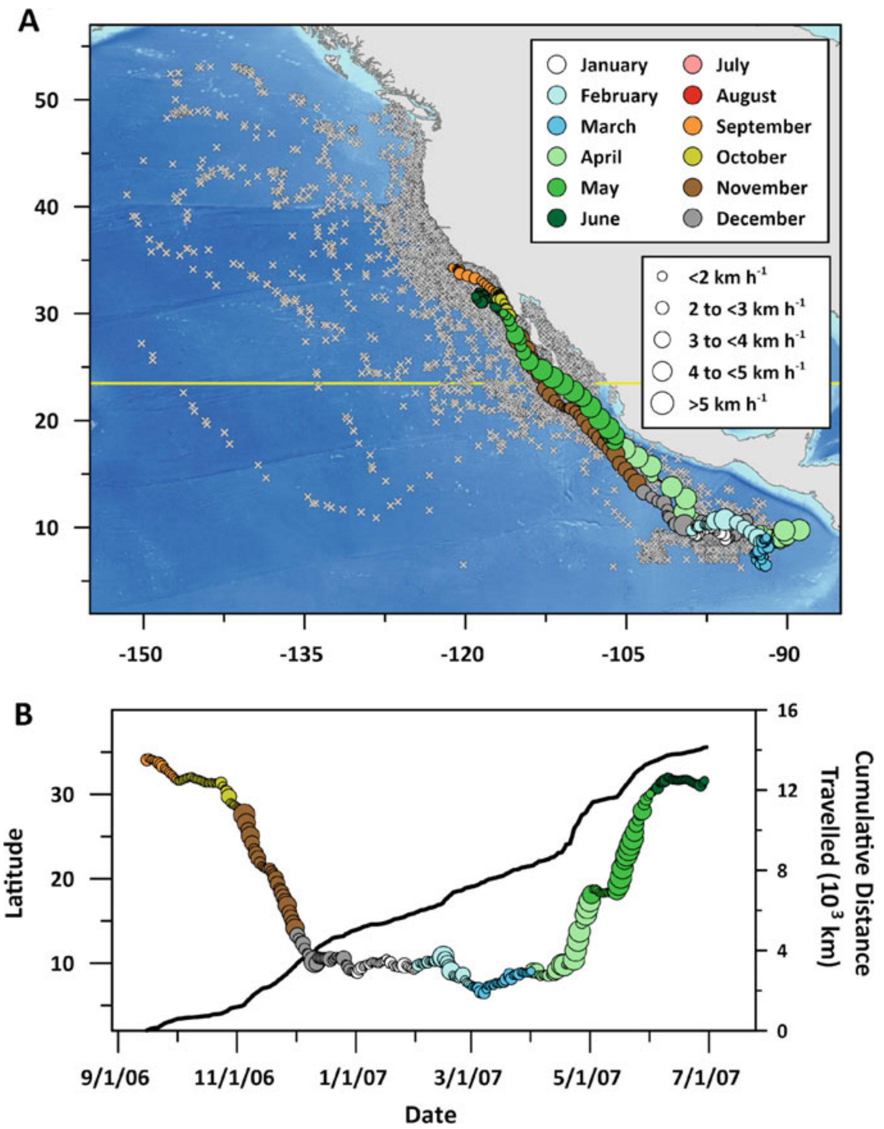

Fig. 4.3 Southward (October–December 2006) and northward (April–May 2007) return migration of satellite tracked blue whale, PTT#2083 (Irvine et al. 2014). Panel **A** presents a plate carrée projection of PTT#2083's satellite-monitored migration across the Northeast Pacific Ocean (circles; size represents swimming velocity and color represents month, as indicated in the legends). Gray crosses show Argos location estimates for 139 different blue whales. Blue-scale marine base map depicts bathymetry, and the Tropic of Cancer is represented by the yellow line. Panel **B** presents Julian calendar timing of PTT #2083's movements with respect to latitude (symbols as in **A**) and cumulative distance traveled (black line plot). An animation of these data can be viewed at: http://animove.org/wp-content/uploads/2019/04/Daniel_Palacios_animate_moveVis.html

Importantly, passive acoustic monitoring data have informed the management and conservation of blue whales globally (Cummings and Thompson 1971; Stafford et al. 2001, 2011; Stafford 2003; Mellinger and Clark 2003; Nieukirk et al. 2004; Širović et al. 2009; Buchan et al. 2015, 2020, Balcazar et al. 2015; Leroy et al. 2016; Shabangu et al. 2019; Torterotot et al. 2020). We now know that blue whales in the tropical Eastern Pacific Ocean and Indian Ocean might belong to sympatric populations of blue whales from different hemispheres (Stafford et al. 1999b; Samaran et al. 2013). Further, acoustic data have been used to look back in time to estimate historical catches of blue whales and assign them to populations based on acoustic data (Monnahan et al. 2014).

Whalers' observations of harvested animals with intermediate characteristics between blue and fin whales led to the discovery that the two species hybridize (Cocks 1887a, b; Berubé and Aguilar 1998), despite not being phylogenetically close (Arnason et al. 2018; Crossman et al. 2016). A particularly well-known living hybrid known as 'Flue' has been seen at least 19 times since 2004 in the North Pacific, both in its summering range off California and in its wintering range in the southwestern Gulf of California, Mexico (Jefferson et al. 2021). Its summer movements between southern and central California were studied with satellite tracking, while genetic analyses revealed its sex (male) and parentage (a blue whale mother and fin whale father; Jefferson et al. 2021).

Hybridization in blue and fin whales appears to be largely unidirectional (male fin x female blue), and while it is an understudied phenomenon in baleen whales, it has been documented in multiple ocean basins, suggesting that its frequency might be underestimated (Pampoulie et al. 2021). If the acoustic features of hybrids are reliably intermediate between the parents, passive acoustic monitoring and tracking might offer a tool to study the frequency and behavioral ecology of living hybrids (e.g., Watkins et al. 2004). For example, it has been hypothesized that the 'Watkins' whale' (also known as the '52-Hz whale') may have been a bluefin hybrid based on the time frequency characteristics of its song, which are intermediate between the two species in the North Pacific (Watkins et al. 2004; Stafford et al. 2007).

*4.2.5 Bryde's Whale (***Balaenoptera edeni***)*

Very little is known about Bryde's whale migratory behaviors. However, at the coarsest level, Bryde's whales are perhaps best considered as a contrast to bowheads: Bryde's whales are only known to inhabit tropical and temperate environments (Kato and Perrin 2009). If bowheads have an affinity for cold, Bryde's whales have an affinity for warmth.

Although they appear to inhabit warm water environments year-round, some Bryde's whales perform directional long-distance migrations. For example, satellite tagging data revealed that a Bryde's whale, tagged off Southern California, swam at least 600 km to the south-southeast (~152° bearing) parallel to the Baja California coast over a period of about one week in mid-October 2015 (Fig. 4.1; Lagerquist et al. 2017; Mate et al. 2018). Unfortunately, the tag ceased transmissions while the whale was still swimming southward at a typical baleen whale migratory swimming speed of ~4 km h^{-1} (Lagerquist et al. 2017; Mate et al. 2018). As abbreviated as it is, this track fits the general pattern of migrating toward the equator during autumn that is characteristic of rorquals.

Satellite tagging of two Bryde's whales in the offshore Western North Pacific also fits the general pattern, demonstrating that >2000 km equatorward migrations can occur as early as mid-summer (Murase et al. 2016). However, other Western North Pacific Bryde's whales appear to prefer spending their summers in the coastal waters off Southern Japan (Kishiro 2018). As one of the lesser understood and least studied rorquals, much remains to be learned about Bryde's whales, including the recently described balaenopterid, Rice's whale (*Balaenoptera ricei*; Rosel et al. 2021), a resident population in the Northern Gulf of Mexico that was formerly considered Bryde's whales (Corkeron et al. 2017).

There have been relatively few passive acoustic studies of Bryde's whales, and most of these have focused on characterizing the acoustic repertoire of the species (Oleson et al. 2003; Heimlich et al. 2005; Figueiredo and Simao 2014). Not one of these multiple studies was temporally or spatially extensive enough to identify potential migratory patterns, but the geographic variation in Bryde's whale signals (Širović et al. 2013) may be useful in identifying migratory patterns given more data. There is, however, evidence of seasonality in detections of Bryde's whale sounds (Kerosky et al. 2012), which could indicate that Bryde's whales are only vocal seasonally or that they migrate out of the range of recorders. Time difference of arrival acoustic monitoring methods has enabled the quantification of Bryde's whale swimming speeds and directions at the local scale off Kauai, HI (Helble et al. 2016).

*4.2.6 Fin Whale (*Balaenoptera physalus*)*

Fin whales are similar to blue whales in their adherence to the overall pattern of predominantly north–south migrations between seasonal habitats. However, year-round presence in some feeding grounds has been documented in some regions (Moore et al. 2006; Stafford et al. 2007), and populations in semi-enclosed and relatively warm waters demonstrate limited seasonal movements (Geijer et al. 2016; Panigada et al. 2017; Jiménez-Lopez et al. 2019).

Results from satellite tagging in the North Atlantic, North Pacific and South Pacific Oceans (Silva et al. 2013; Scales et al. 2017; Sepúlveda et al. 2018; Irvine et al. 2020), passive acoustic monitoring (e.g., Aulich et al. 2019; Davis et al. 2020); photographic identification (e.g., Gauffier et al. 2018), and analysis of whale ship records (Mizroch et al. 2009) generally support predominantly north–south migration. Feeding locations are not well known, as fin whales in both the Atlantic Ocean and Pacific Ocean exhibit movement behaviors consistent with area-restricted search (ARS) for prey in both temperate (Silva et al. 2013; Sepúlveda et al. 2018; Jiménez López et al.s 2019) and circumpolar environments (Silva et al. 2013; Irvine et al.

2020). However, seasonal migrations can be inferred given that discovery marking and harvests of fin whales in summer months in the northernmost Pacific regions were concentrated in a number of hotspots and that catches declined dramatically by October (Mizroch et al. 2009).

Less is known about fin whale breeding/calving ground locations compared to feeding locations. A global synthesis of post-whaling era fin whale distribution data, including visual surveys and acoustic monitoring, suggests an equatorial hiatus (ca. 20° N to 20° S) in fin whale distribution (Edwards et al. 2015). However, open ocean sightings demonstrate that fin whales have been known to congregate in the tropical South Pacific Ocean, notably thousands of kilometers from shore, in late autumn, presumably for reproductive purposes (Acevedo et al. 2012), and the recent sighting of a solitary fin whale off the coast of Colombia (ca. 10°N) is another exception to the equatorial hiatus hypothesis (Acosta et al. 2020). More localized acoustic tracking of fin whales (e.g., Soule and Wilcock 2013; Wiggins and Hildebrand 2020) has helped reveal whale movements, facilitating conservation and management in these areas.

The observation of young fin whales entering the North Atlantic via the Strait of Gibraltar (Gauffier et al. 2018) suggests that calving of migratory Northeast North Atlantic (i.e., Castellote et al. 2010) and resident whales (Geijer et al. 2016) occur in the 35° N to 45° N latitude Mediterranean Sea. Although more data are needed, satellite tagging of six migrating whales in the North Atlantic Ocean revealed that fin whales are fast, exhibiting an overall migratory swimming speed of nearly 8 km h^{-1} (Silva et al. 2013). Clarke (2004) suggests that the distribution and movement behaviors of pygmy fin whales in the Southeast Pacific are similar to those of pygmy blue whales.

*4.2.7 Minke Whale (***Balaenoptera acutorostrata***; ***B. bonaerensis***)*

Both common (*B. acutorostrata*) and Antarctic (*B. bonaerensis*) minke whales follow the general pattern of baleen whale migration exemplified by humpback whales and other balaenopterids. Satellite tracks (e.g., Vikingsson and Heide-Jørgensen, 2015; Lee et al. 2017), passive acoustics (e.g., Risch et al. 2014; Shabangu et al. 2020), discovery marks (Horwood 1990), and photo-identification (e.g., Gill and Fairbainrns 1995) results suggest that minke whales in both hemispheres perform long-distance return migrations between circumpolar feeding areas and temperate to tropical breeding/calving areas. The dwarf minke whale is an unnamed subspecies to the common minke whale, and their seasonal occurrence in low-latitudes (Arnold et al. 1987; Zerbini et al. 1996) suggests the movement behaviors of dwarf and common minkes are likely similar.

Although minke whales are more difficult to study than many other baleen whales, in part due to their elusive behaviors and pelagic habitat (Risch et al. 2019), it is clear that minke whales are capable of ~7000 km one-way migrations from Antarctic to equatorial waters (Lee et al. 2017), with migratory swimming speeds ranging between 4.6 and 7.3 km h^{-1}. Equatorward migrations tend to occur in autumn, while poleward migrations tend to occur in spring (Risch et al. 2014; Vikingsson and Heide-Jørgensen 2015; Lee et al. 2017). Although the duration of seasonal residency and locations of minke whales in warmer water environments is one of the lesser-known aspects of their migratory pattern, the common occurrence of cookie-cutter shark (*Isistius brasiliensis*) bites and the commensal pseudostalked barnacle (*Xenobalanus globicipitis*) on minke whales provides compelling evidence of seasonal residence in warmer water environments (Towers et al. 2013). In a novel demonstration of the incredible nuances present in long-distance baleen whale movement behaviors, genetic studies have demonstrated that Antarctic minke whales have migrated to the Arctic (Glover et al. 2010), and that the two species have successfully crossbred and back-crossbred (Glover et al. 2013).

*4.2.8 Omura's Whale (***Balaenoptera omurai***)*

Very little is known about Omura's whales, which were only recently described as a species (Wada et al. 2003, Chap. 15). Research in Madagascar suggests Indian Ocean Omura's whales do not undertake seasonal long-distance migrations (Cerchio and Yamada 2018). In stark contrast to most other baleen whales, Omura's whales seem to both feed and breed/calve in tropical to temperate waters of the Indian and Western Pacific Oceans. However, the recent discovery of Omura's whales in the central equatorial Atlantic (Moreira et al. 2020) demonstrates that there remains much to be learned about this cryptic balaenopterid.

*4.2.9 Sei Whale (***Balaenoptera borealis***)*

The migratory behavior of sei whales is more like that of fin whales, despite sei whales being more closely related to Bryde's whales (Rosel and Wilcox 2014) and blue whales (Árnason et al. 2018) than fin whales. As a predominantly oceanic species, sei whales are inherently difficult to study. However, results from satellite tagging (Olsen et al. 2009; Prieto et al. 2014), passive acoustic (e.g., Nieukirk et al. 2020), and photo-identification studies (Weir et al. 2020) and analysis of whaling records (Horwood 1987; Gregr et al. 2000) provide a strong foundation for our current understanding of sei whales. Sei whale migrations connect lower-latitude calving areas to circumpolar feeding areas (Horwood 2009).

Like fin whales, sei whales are fast swimmers, with average migratory swimming speeds of ~ 7.4 km h^{-1} (Prieto et al. 2014). Passive acoustic monitoring in Fram Strait (ca. 79° N), in the polar North Atlantic near Svalbard, recorded sei whale vocalizations as early as May and as late as October, with annual peaks in the summer (Nieukirk et al. 2020). These data suggest that poleward migrations occur in spring, and equatorward migrations occur in autumn over periods of 4–8 weeks, as supported by satellite tracking (e.g., Prieto et al. 2014) and analysis of whaling records (e.g., Gregr et al. 2000).

4.2.9.1 Gray Whale (*Eschrichtius robustus*)

The migratory movements of Eastern North Pacific gray whales are relatively well studied. This large body of knowledge derives from the fact that this population of gray whales migrates in a north–south migratory corridor close to shore along the west coast of North America (Lagerquist et al. 2019), facilitating data collection and monitoring. Visual and acoustic surveys have confirmed that Eastern North Pacific gray whales migrate between calving/breeding grounds in Baja California Sur and feeding grounds in the Northeast Pacific (Lagerquist et al. 2019), and Chukchi Seas (Fig. 4.4). Gray whales depart their northern feeding grounds in autumn, pass Granite Canyon, California, from late December through early February, and arrive in their Baja California breeding areas a week or two later (Rugh et al. 2001). The onset of the northward migration peaks in early March (Swartz et al. 2007), with most whales migrating past Vancouver Island in the second-half of March (Burnham and Duffus 2020). Gray whales are known to arrive off Sivuqaq (St. Lawrence Island, ca. 63° N) in May and June (Pike 1962).

Although based on relatively small datasets, satellite tagging data demonstrate that migrating gray whales are relatively fast swimmers, maintaining northward and southward average speeds of 5.5–6.5 km h^{-1} (Mate and Urban-Ramirez 2003; Mate et al. 2015). Importantly, gray whale satellite tracking across the Sea of Okhotsk, Bering Sea, and Gulf of Alaska (Mate et al. 2015) adds two unexpected insights to our understanding of gray whale migratory behavior: (1) rather than solely relying on nearshore orientation cues, gray whales are also exceptional open ocean navigators as they cross the North Pacific Ocean when moving from feeding habitats off the Russian Far East toward the North American coast (Fig. 4.4; Mate et al. 2015); and (2) the status of Western North Pacific gray whales, a population once thought to be extinct, remains ambiguous (Mate et al. 2015).

4.2.9.2 Humpback Whale (*Megaptera novaeangliae*)

Humpback whale annual movements between tropical calving/breeding grounds and mid-latitude to high-latitude feeding areas, often with high levels of feeding and breeding area site fidelity (e.g., Calambokidis et al. 2001; Horton et al. 2017), represent a quintessential baleen whale behavior. Humpback whale migrations, some of the longest distance mammalian migrations (Rasmussen et al. 2007; Robbins et al. 2011), connect productive higher-latitude feeding ecosystems to nutrient-deficient tropical areas. These migrations help cycle limiting nutrients like nitrogen and iron via excretion (e.g., feces, urine, sloughed skin) and vertical mixing of the water column caused by their surface and diving behaviors (e.g., Doughty et al. 2016).

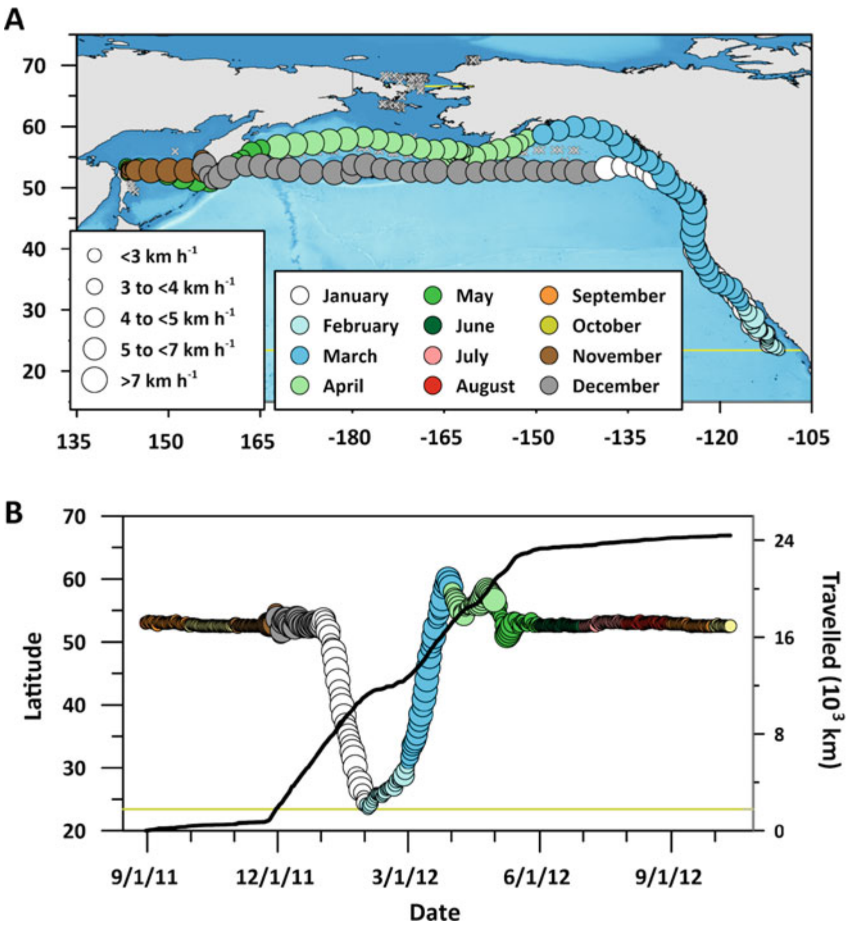

Fig. 4.4 Eastward (November–December, 2011), then southward (January, 2012), and northward (February–March, 2012), then westward (April–May, 2012) return migration of satellite tracked gray whale, PTT#1388 (Mate et al. 2015). Panel A presents a plate carrée projection of PTT#1388's satellite-monitored migration across the North Pacific Ocean (circles; size represents swimming velocity and color represents month, as indicated in the legends). Gray crosses show Argos location estimates for 12 different gray whales. Blue-scale marine base map depicts bathymetry, and the Tropic of Cancer is represented by the yellow line. Panel B presents Julian calendar timing of PTT #1388's movements with respect to latitude (symbols as in A) and cumulative distance travelled (black line plot)

Similar to gray whales, humpback whale migratory behaviors are relatively well documented. Poleward migrations typically occur during spring, and the return equatorward migrations tend to happen in late autumn (Fig. 4.5). Humpback whale migratory swimming speeds appear to range between 3 and 8 km h^{-1} across vast expanses of open ocean or parallel to coast lines, with some whales maintaining slower or faster swimming speeds for the duration of their ~6-week-long migrations (e.g., Horton

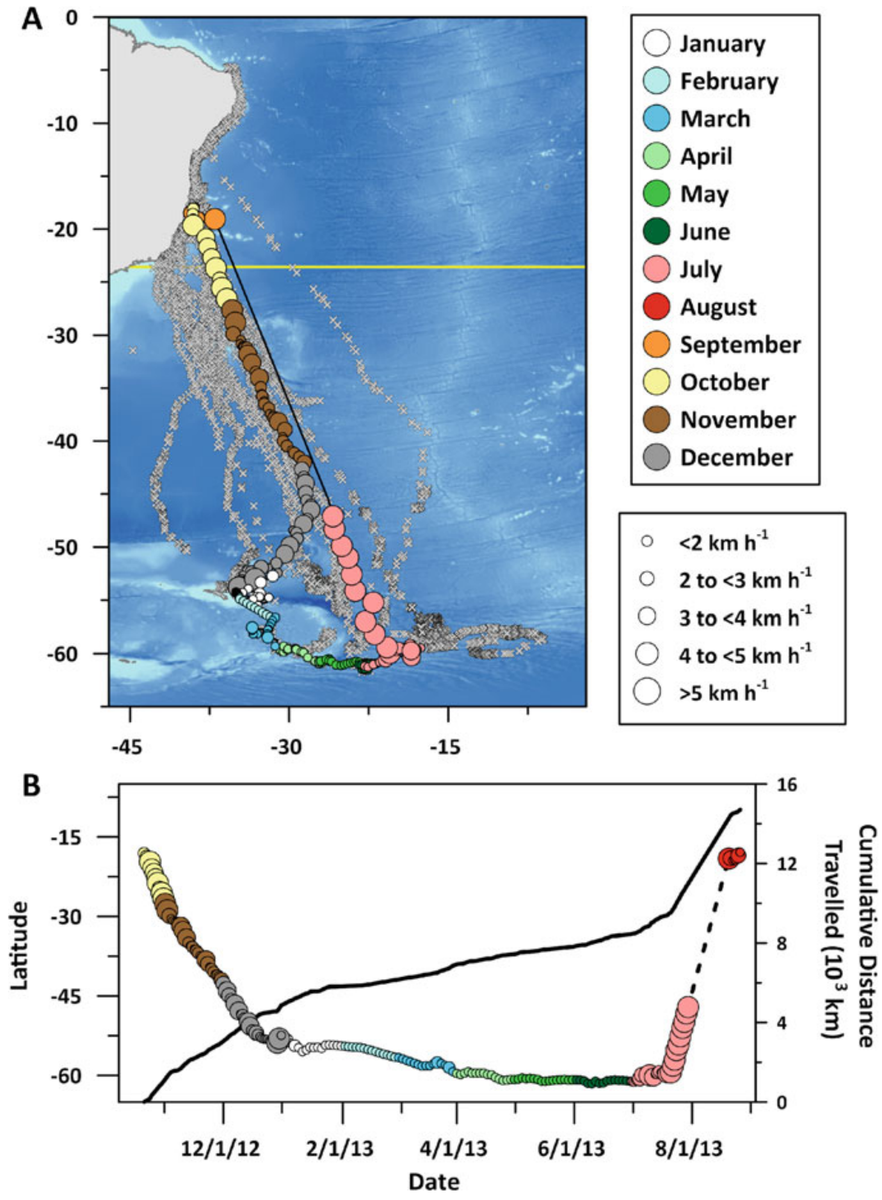

Fig. 4.5 Southward (October–December 2012) and northward (July–August 2013) return migration of satellite tracked humpback whale, PTT#121189 (Horton et al. 2020; this study). Panel **A** presents a plate carrée projection of PTT#121189's satellite-monitored migration across the Southwest Atlantic Ocean (circles; size represents swimming velocity and color represents month, as indicated in the legends). Gray crosses show every third Argos location estimates for 137 different humpback whales. Blue-scale marine base map depicts bathymetry, and the Tropic of Capricorn is represented by the yellow line. Panel **B** presents Julian calendar timing of PTT #121189's movements with respect to latitude (symbols as in **A**) and cumulative distance traveled (black line plot)

et al. 2020). Humpbacks are capable of maintaining remarkably directional (i.e., low variability in heading) movements during migration or migratory segments (Horton et al. 2011), and large proportions of regional populations appear to maintain migratory route fidelity to open-ocean corridors for 50 years or more (Horton et al. 2020). Interestingly, different humpback whale populations cross both the geographic and magnetic equators (Fig. 4.1; Rasmussen et al. 2007) and one or more ocean basins while migrating (Forestell 2007; Stevick et al. 2011, 2016; Félix et al. 2020).

A number of insights into humpback whale migrations demonstrate both agreement with the simplified general migratory pattern of many baleen whales and novel, but poorly understood, behaviors. Detailed analyses of humpback whales killed during the whaling era and long-term photographic identification results provide a strong basis of knowledge for this species (e.g., Chittleborough 1958; Craig et al. 2003). The timing of humpback whale migrations appears to be correlated with age, sex, and reproductive status (Chittleborough 1958; Craig et al. 2003). Juveniles and females without calves arrive on lower-latitude breeding/calving grounds earlier than adult males and females with calves; juveniles and females without calves also depart breeding/calving grounds earlier (Craig et al. 2003). The timing of humpback whale migrations is likely related to the different energy requirements of whales in different stages of development or reproductive status (Craig et al. 2003), and as extreme examples of capital breeders, humpback whales appear to balance the energy trade-offs of feeding, migrating, and breeding by optimizing swimming velocity during migration and the amount of time spent resting versus traveling (Braithewaite et al. 2015).

However, the total amount of time individual humpbacks spend migrating relative to residing in breeding/calving/feeding areas remains largely unknown. The small number of satellite tags (n = 9) that have transmitted for longer than 160 days reveals that poleward migrations can be as short as 30 days and as long as 60 days. The solitary humpback tracked across a complete annual migratory cycle (PTT 121189; Fig. 4.5), a male Western South Atlantic humpback, spent ~60 days migrating poleward during mid-late spring, ~210 days in feeding areas during summer and autumn, and ~30 days migrating equatorward during summer. Although humpback whales typically follow the general pattern of seasonal annual migration between higher-latitude feeding grounds and lower-latitude breeding and calving grounds (excluding the Arabian Sea population; Pomilla et al. 2014), there appears to be a high level of variability in the spatiotemporal dynamics of humpback whale migrations.

Technology-driven knowledge of humpback whale migratory behaviors has led to a number of distinctive conservation impacts. For example, satellite tracking of humpback whales in the Eastern Pacific (Guzman et al. 2013) led to the creation of a ‘Whale Avoidance Strategy’ for year-round vessel management in the Gulf of Panama, where more than 17,000 commercial ships pass between the Atlantic and Pacific each year. The spatially and temporally dynamic strategy was specifically designed to reduce, by as much as 93%, the potential for collision-induced whale trauma in one of the world’s busiest shipping lanes (Guzman et al. 2013). Similarly, in central Polynesia, satellite tracking of humpback whales (Hauser et al. 2010; Horton et al. 2017) helped inform the identification and management of special, unique marine areas, or SUMAs, within the Cook Islands Marine Park—Marae Moana, which at 1.98 million km^2 is currently the world's largest marine protection area. By revealing when and where individual whales are located, satellite tracking can provide precise spatial and temporal information that is fundamental to the development of successful conservation strategies, marine protection, and sustainable management (e.g., de Castro et al. 2014; Panigada et al. 2017).

4.3 Part II: Biological Impacts of Technology

Technology has played a crucial role in advancing our understanding of baleen whale migratory behavior. For example, satellite tagging has allowed researchers to identify, with relatively high precision and accuracy, when and where whales are located. The resulting latitude, longitude, date, and time data have helped identify previously unknown whale habitats, migration routes, and movement attributes, including speed, direction, and minimum distance traveled. When combined with oceanographic, environmental, and geophysical datasets and models, deeper insights can be made regarding why certain whales do the remarkable things they do.

Passive acoustic monitoring has also had a major impact. For example, migratory pathways, including changes in the phenology of baleen whales, have been inferred by treating widely spaced hydrophones as 'turnstiles' by which the population passes at different times of the year. In the Western North Atlantic, an acoustic study determined that five different species of baleen whale (blue, fin, sei, humpback, and right) shifted their distributions northward over a decade, and these shifts likely reflected climate-related changes in the phenology of their disparate prey species (Davis et al. 2017, 2020). In this same region, some of these same acoustic datasets were used to document the movements of minke whales from low-latitude breeding grounds to higher-latitude feeding grounds and how the migration corridor varied based on time of year (Risch et al. 2014). Below, we briefly summarize two specific topics, whale navigation and hotspots, where technological advances were fundamental to elevating our knowledge and understanding of baleen whale migration.

4.3.1 Insights into Whale Navigation

Although the specific mechanisms by which baleen whales navigate remain unknown, a number of hypotheses have been proposed. In the mid-1980s, Kirschvink et al. (1986) hypothesized that cetacean orientation and navigation are informed by the topography of the Earth's magnetic field based on significant correlations between whale stranding sites and geologically induced local magnetic minima. Likewise, studies of satellite-tagged humpback whales found that animals have the ability to maintain highly directional headings during long-distance migrations (Mate et al. 1998; Horton et al. 2011). The potential linkage between cetacean navigation and the temporal dynamics of the Earth's magnetic field has been proposed as a causal contributor to whale stranding events (Vanselow et al. 2018; Vanselow 2020). A more recent analysis, however, did not find any statistical associations between globally distributed whale stranding datasets and magnetic storms documented in the instrumental record (Pulkkinen et al. 2020). Four key points emerge: (1) The influence of the Earth's magnetic field on cetacean orientation and navigation remains ambiguous; (2) deeper understanding is developed through the integration of seemingly disparate sub-disciplines (e.g., biology, geology, physics, and astronomy); (3) the mechanisms and mechanics of baleen whale navigation remain unknown; and (4) technological advances, including high-resolution mapping of Earth's magnetic and gravitation fields, facilitate both abductive and inductive approaches to elucidating how whales most likely navigate.

The interdisciplinary application of recent technological innovations has also enabled new interpretations of baleen whale navigation. For example, Horton et al. (2017) found that temporally and spatially dynamic gravitational cues were stronger predictors of humpback whale migrations than magnetic cues. In this example, technological advances created an unprecedented opportunity to explore the geophysical context of biological behaviors. Specifically, NOAA's satellite-derived Enhanced Magnetic Model (Maus 2010), a more accurate tool for quantifying the combined bedrock and main field magnetic variables at a given place and time, and the satellite-derived World Gravity Map (Balmino et al. 2012) were combined with humpback whale satellite tracking data in an empirical analysis of the geophysical cues whales experienced at the individual level. Such biogeophysical approaches are relatively new and represent an important integrated approach to solving the enduring mystery of how whales navigate.

4.3.2 Identifying Whale Hotspots

Anticipating when and where whales will be located is one of the biggest challenges of cetacean ecology. Most whales are difficult to study due to their reclusive behavior and large, and often highly inaccessible, oceanic home ranges. Passive acoustics represents an important, noninvasive technological advance that has started to advance our understanding of baleen whale hotspots. For example, long-term acoustic monitoring in the Juan Fernandez Archipelago, Chile, revealed that blue, fin and/or minke whales are present in the area during most weeks of the year (Buchan et al. 2020). Acoustic monitoring has also been a key tool in documenting the return of endangered whales to the vicinity of South Georgia Island, a pre-whaling hotspot of cetacean biodiversity (Jackson et al. 2018; Calderan et al. 2020).

Satellite tracking has proven to be a remarkably valuable tool for understanding baleen whale migrations and describing previously unknown movement patterns and whale hotspots. For example, humpback whale satellite tagging studies in the North Pacific and the Southern Hemisphere identified migratory corridors and important offshore feeding habitats (Zerbini et al. 2006, 2011; Andrews-Goff et al. 2018; Riekkola et al. 2018; Horton et al. 2020). Satellite tracking has also revealed novel diving behaviors and an association with seamounts in remote low and middle-latitude migration routes (Mate et al. 2007; Garrigue et al. 2015; Derville et al. 2019). Intensive and prolonged whale satellite tracking in the Bering, Chukchi, and Beaufort Seas helped identify a number of bowhead whale hotspots (i.e., core-use areas; Citta et al. 2015). Similarly, another prolonged satellite tracking campaign off the west coast of the USA helped not only identify the areas of highest use for feeding blue whales, but also the extent of their overlap with busy shipping lanes (Irvine et al. 2014). Robust datasets like these create powerful opportunities to anticipate and assess the impacts of the current period of rapid environmental, oceanographic, and climatic change on the health and behavior of baleen whales.

Integrated biological, oceanographic, climatic, and geophysical approaches are already underway (e.g., Abrahms et al. 2019b, Rockwood et al. 2020). Along the California coast, blue and humpback whale and krill survey data, collected as part of the Applied California Current Ecosystem Studies (ACCESS) program, were integrated with a variety of ocean variables and climate indices to produce a rigorous data-driven predictive model of when and where whales might occur (Rockwood et al. 2020). In the shipping lanes of Boston, passive acoustic monitoring has recorded North Atlantic right whales since 2009 (https://portal.nrwbuoys.org/ab/dash/), and another initiative called WhaleWatch 2.0 (https://coastwatch.pfeg.noaa.gov/projects/whalewatch2/about_whalewatch2.html) generates near-real-time online predictions of blue whale occurrence as a decision support tool to minimize ship strike risk (Abrahms et al. 2019b). Further, incorporation of stakeholder input into potential risk scenarios has proved fruitful in generating more informed management measures (Redfern et al. 2019).

4.4 A Look to the Horizon

Understanding baleen whale migration is strongly aligned to the United Nation's Decade of Ocean Science for Sustainable Development (2021–2030). The Intergovernmental Oceanographic Commission (IOC) states that, 'The main purpose of the International Decade of Ocean Science for Sustainable Development would be therefore to seek and communicate scientific solutions to the problems,' (IOC-UNESCO 2017). According to the IOC, specific goals of the 'Decade' include: (1) reversing ocean degradation; (2) filling identified knowledge gaps; (3) promoting good ocean stewardship; (4) mapping and quantifying the state of the ocean; (5) establishing sustained ocean observation; (6) strengthening interdisciplinary ocean research; (7) making technology, modeling tools, and training more accessible; (8) enhancing trust, cooperation, coordination, information exchange, communication, and education. Advancing our understanding of how and why baleen whales migrate, within the context of rapidly changing climate and ocean health, would support these long-term goals. Indeed, the themes of the future are not unlike the themes of the past, as espoused by Lythberg and Ngata's (2019) whale–human synergy.

Kaitiakitanga/guardianship, mātakitaki/observing, mātauranga/knowledge, and kotahitanga/unity will remain pillars of the relationship that connects humans, oceans, and whales, no matter what the future holds. With respect to baleen whale migration, the scientific community is perhaps at a turning point where its attention shifts from describing who, what, where, and when, to answering the questions of why and how. For example: Why are some migratory whale populations, including North Atlantic right whales and South Pacific humpback whales (i.e., Paikea; Lythberg and Ngata 2019), not recovering as quickly as others? How will migratory whales respond to changing seascapes and continued ocean development?

Realizing the complementary goals of sustainable migratory baleen whale populations and healthy oceans requires both a willingness to learn and a commitment to change. We suggest that looking to the past, while acting in the present, will help us navigate toward a more sustainable future for both humans and whales. Or, as another whakataukī more elegantly puts it:

> Kia whakatōmuri te haere whakamua.
>
> I walk backwards into the future with my eyes fixed on my past.
>
> (Rameka 2016).

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