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Echoes in the Deep: The Struggle of Bryde's Whales in Indian Waters

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ABSTRACT: Bryde's whale (*Balaenoptera edeni/brydei*) is a baleen whale species distributed in tropical and subtropical waters, comprising two recognized subspecies: the smaller inshore *B. e. edeni* and the larger offshore *B. e. brydei*. Genetic and morphological studies suggest additional distinct lineages, indicating complex taxonomy and localized adaptations. These whales exhibit opportunistic feeding, primarily on pelagic fish and zooplankton, with seasonal movements often tied to prey availability. While globally listed as "Least Concern" by the IUCN, specific populations, such as the critically small group in the Gulf of Mexicoface serious threats from vessel strikes, fisheries interactions, and climate change. In Indian waters, sightings and stranding, particularly along the Odisha coast and in the Sundarbans, highlight a potentially understudied population that may use the region seasonally or residually. The post-monsoon season coincides with high prey availability, suggesting feeding-related habitat use. Conservation efforts in India and globally must focus on improved monitoring, localized threat assessments, and integrated strategies involving genetic research, acoustic surveys, and stakeholder collaboration. Targeted protection of key habitats and mitigation of anthropogenic impacts are essential to ensure the long-term survival of this ecologically important yet vulnerable species.

Keywords: Cetacean conservation, tropical marine mammals, inshore and offshore subspecies, whale stranding, Indian waters, anthropogenic threats, vessel strikes.

INTRODUCTION

The Bryde's whale, belonging to the genus *Balaenoptera*, is a fascinating and ecologically important cetacean predominantly found in tropical and subtropical waters. Currently, there are two recognized subspecies of Bryde's whale: *Balaenoptera edeni*, often referred to as Eden's whale, and *Balaenoptera brydei*, which inhabits offshore regions and is generally larger. This differentiation is supported by genetic analyses and morphological studies, indicating significant population isolation between inshore and offshore forms, particularly in regions like southern Africa and the Gulf of Mexico (Penry *et al.*, 2018; Izadi *et al.*, 2022; Kershaw *et al.*, 2013). Bryde's whales primarily feed on small pelagic fish and zooplankton, displaying feeding behaviours that reflect their adaptations to different ecological niches (Kahane-Rapport and Goldbogen 2018; Purdon *et al.*, 2020). The inshore population often competes with commercial fisheries for these critical food sources, leading to heightened vulnerability to anthropogenic pressures (Purdon *et al.*, 2020; Thomas *et al.*, 2015; Segre *et al.*, 2022). Recent studies have shown that Bryde's whales are subject to a variety of threats, including fisheries bycatch, vessel strikes, and climate change-induced habitat alterations (Thomas *et al*., 2015; Rosel and Wilcox 2014). These stressors are compounded by the species' relatively low population densities and the specific habitat requirements of different subspecies (Rosel and Wilcox 2014; Soldevilla *et al*., 2017).

As our understanding of Bryde's whale populations evolves, there is a growing consensus among marine scientists and conservationists regarding the urgent need to reassess their conservation status. The International Union for Conservation of Nature (IUCN) lists Bryde's whales as of "Least Concern," yet this classification may underrepresent the vulnerability of specific populations due to their localized nature (Murase *et al*., 2007; Wang *et al*., 2022). Notably, the population in the northern Gulf of Mexico has been reported to consist of only about 33 individuals, highlighting the immediate conservation needs for this specific population (Rosel and Wilcox 2014; Soldevilla *et al*., 2017).

Furthermore, recent research has illuminated the complex social behaviours and vocalizations of Bryde's whales, drawing attention to their potential social structures and migratory patterns (Hodge *et al*., 2015; Allen *et al*., 2024; Smultea *et al*., 2010). Understanding these dynamics is essential for effective management and conservation strategies, as it informs how these whales interact with their environment and respond to

human-induced changes (Murase *et al*., 2007; Hodge *et al*., 2015). When examining the population structure of Bryde's whales, genetic evidence reveals distinct lineages adapted to their respective environments across the globe (Kershaw *et al*., 2013; Pastene *et al*., 2015). Comparative studies of morphological traits and call types across different regions have provided insights into their evolutionary trajectories, suggesting that localized adaptations may play a critical role in their resilience or vulnerability to environmental change (Durfort *et al*., 2020; Oleson *et al*., 2014).

While the current status of Bryde's whales indicates that they are not at immediate risk of extinction globally, the precariousness of certain populations necessitates ongoing research and conservation efforts. As anthropogenic threats continue to escalate, it is pivotal to enhance our understanding of Bryde's whales through comprehensive ecological and genetic studies, ultimately leading to more effective monitoring and protective measures aimed at ensuring their survival in increasingly changing marine environments. Therefore the present study is focused on representing the status of this Bryde's whales along Indian waters

Morphology. The morphology of Bryde's whales is a subject of great interest due to its implications for taxonomy, behaviour, and conservation strategies. Bryde's whales are characterized by their streamlined bodies, which typically range from 12 to 15 meters in length, making them one of the smaller members of the rorqual family. A distinctive feature of Bryde's whales is the presence of three parallel longitudinal ridges running from the blowhole to the tip of the rostrum, which serves as an important identifying characteristic that distinguishes them from other cetaceans (Rosel *et al*., 2021; Purdon *et al*., 2020; Best, 2001).

Recent investigations have revealed significant morphological variations between the two recognized subspecies of Bryde's whales. The larger *B. e. brydei* commonly inhabits offshore waters and displays a more robust body structure, while the smaller *B. e. edeni* tends to be found in more coastal environments, exemplifying unique adaptations suited to its respective habitat (Rosel *et al*., 2021; Purdon *et al*., 2020). Such distinctions are critical for proper identification, informed management practices, and understanding the ecological roles these whales play in their environments (Penry *et al*., 2018).

The skull morphology is particularly integral for distinguishing Bryde's whales from closely related species, such as Omura's whale (*B. omurai*). Studies integrating genetic and morphological data have armed researchers with more reliable taxonomic classifications, underscoring how variations in skull structure, found in typical samples, can inform species designations (Rosel *et al*., 2021; Kanda *et al*., 2006; Luksenburg *et al*., 2015). Genetic studies have also indicated a substantial divergence in populations, showing that morphological traits closely align with genetic differentiation, further complicating the taxonomic landscape for this group of whales (Rosel and Wilcox 2014; Penry *et al*., 2018).

In addition to skull characteristics, the overall body proportions of Bryde's whales can vary significantly based on geographic location and environmental conditions. For instance, Bryde's whales examined off the coast of southern Africa exhibited morphological adaptations relevant to local ecological conditions, such as varying body length and fin shape (Best, 2001). The variability has been employed as a foundation for ongoing assessments into the dynamics of Bryde's whale populations and their interactions with fisheries, highlighting the implications of their morphology on local biodiversity (Gonçalves *et al*., 2015; Segre *et al*., 2022).

Biology. The biology of Bryde's is characterized by a variety of physiological and ecological traits that support their survival in diverse marine environments. Notable for their streamlined bodies and distinctive dorsal ridges that facilitate hydrodynamics, Bryde's whales have evolved various adaptations that contribute to their foraging efficiency and reproductive strategies (Siciliano *et al*., 2004; Maciel *et al*., 2016). Their morphology is that of a robust rorqual, typically measuring between 12 to 15 meters in length for the smaller subspecies (*B. e. edeni*) and larger for the offshore form (*B. e. brydei*) (Barbieri *et al*., 2020; Maciel *et al*., 2016). These morphological features play a pivotal role in their feeding behaviour, which primarily consists of lunge feeding and other strategies adapted to capture small schools of fish and zooplankton (Izadi *et al*., 2022; Bando *et al*., 2017).

In terms of diet, Bryde's whales are recognized as opportunistic feeders, adapting their foraging tactics based on prey availability and environmental conditions (Hiwasa *et al*., 2009; Izadi *et al*., 2022). Data indicates they primarily feed on small pelagic fish, notably sardines, which draw Bryde's whales closer to coastal waters during spawning seasons (Siciliano *et al*., 2004; Maciel *et al*., 2016). Their feeding presence is frequently documented in areas with high sardine concentrations, particularly in regions like Brazil's Cabo Frio, which exhibit significant fish abundance (Maciel *et al*., 2016; Gonçalves *et al*., 2015). Moreover, their dietary habits can change seasonally, indicating a plasticity that allows them to exploit varying ecological niches effectively (Rosel *et al*., 2021; Izadi *et al*., 2022).

Reproductive behaviour in Bryde's whales is also uniquely adapted to their environment. Unlike many baleen whales that have distinct breeding seasons, Bryde's whales tend to breed throughout the year, which is likely an adaptation to the consistently warm waters they inhabit (Hiwasa *et al*., 2009; Ferreira *et al*., 2021). This continuous reproductive strategy can confer advantages in sustaining stable population levels within their habitats. Social behaviour among Bryde's whales tends to be relatively solitary or loosely organized into small groups, often influenced by local prey availability. This foraging structure implies that competition for resources can be minimized in favour of cooperative behaviours during feeding (Siciliano *et al*., 2004; Constantine *et al*., 2018). Furthermore, studies report vocalizations among Bryde's whales that can convey vital information regarding their presence and movements within their habitats, which highlights the importance of communication for both foraging and

social interactions (Wang *et al*., 2022; Helble *et al*., 2024). Seasonality plays a crucial role in the ecology of Bryde's whales, as evidenced by their migratory patterns that coincide with environmental changes. Research has shown that local populations remain in specific areas depending on seasonal prey availability and oceanographic conditions (Zhang *et al*., 2023; Best, 2001). The implications of these findings suggest that habitat conservation and protection of critical feeding grounds will be paramount for the long-term sustainability of Bryde's whale populations (Zhang *et al*., 2023; Ferreira *et al*., 2021).

Taxonomy. The taxonomy and systematics of Bryde's whales, specifically within the genus *Balaenoptera*, present intriguing and complex challenges for cetologists. Traditionally, Bryde's whales have been classified into two primary subspecies: *B. edeni edeni*, known as the inshore form, and *B. edeni brydei*, recognized as the offshore form (Boer, 2010; Purdon *et al*., 2020). This classification is supported by significant morphological and genetic differences that have emerged from various studies. For instance, notable distinctions in size and habitat preference have been observed, with *B. e. brydei* typically inhabiting deeper oceanic waters compared to its coastal counterpart (Boer, 2010; Siciliano *et al*., 2004; Soldevilla *et al*., 2017). The delineation of these subspecies is further complicated by ongoing debates regarding their phylogenetic relationships and potential separate species status. Recent genetic evaluations suggest that the Bryde's whale complex may actually comprise more than the two recognized forms, with evidence of unique lineages appearing in distinct geographic regions (Constantine *et al*., 2018; Rosel *et al*., 2021). For example, the genetic diversity of Bryde's whales in the northern Gulf of Mexico indicates a unique evolutionary lineage that is notably different from the recognized subspecies (Soldevilla *et al*., 2017).

A pivotal study examining Bryde's whales in southern Africa proposed that these whales should be classified under *B. brydei* based on morphological and genetic data (Purdon *et al*., 2020; Penry *et al*., 2018). Similarly, subspecies recognition has evolved as new information arises, with some researchers advocating for the separation of these whales into distinct species based upon findings that highlight significant ecological adaptations and behavioural differences informed by local environments (Constantine *et al*., 2018; Rasmussen and Palacios, 2023; Rosel *et al*., 2021). This complexity mirrors broader issues in marine mammal taxonomy, where morphological similarities often mask underlying genetic differences.

The distribution patterns of Bryde's whales also underscores their taxonomic complexity. They are found in temperate and tropical waters globally, leading to conjectures that various populations may exhibit distinct ecological behaviours tailored to their environments (Constantine *et al*., 2018; Soldevilla *et al*., 2017; Gough *et al*., 2021). For instance, whales in the Hauraki Gulf of New Zealand have been classified under *B. edeni* due to observed feeding patterns and seasonal behaviours, where they are the most frequently sighted balaenopterids (Wiseman *et al*., 2011; Gonçalves *et al*., 2015). Furthermore, acoustic studies indicate variations in vocalizations associated with different populations, which may serve as another taxonomic differentiator (Wang *et al*., 2022; Helble *et al*., 2016).

The ongoing study of the taxonomy of Bryde's whales underscores the importance of integrating genetic analyses, ecological data, and morphological assessments to achieve a comprehensive understanding of their systematics. This knowledge is critical for conservation efforts, as misclassification can hinder appropriate management strategies (Constantine *et al*., 2018; Cerchio *et al*., 2015; Athayde *et al*., 2022).

Identification. Bryde's whales can be reliably recognized by their three prominent ridges, which run parallel to the rostrum from the blowhole to the tip of the snout, a distinctive trait that differentiates them from other rorqual whales. This characteristic ridge structure is crucial for accurate identification, particularly in regions where Bryde's whales coexist with similar species (Ren *et al*., 2022; Athayde *et al*., 2022).

Given their size and morphological features, Bryde's whales typically exhibit a streamlined body and a dorsal fin that is falcate and located approximately two-thirds of the way back along their body. They usually possess a lighter coloration on their ventral side, often making them appear somewhat Gray or bluish from a distance (Ren *et al*., 2022; Athayde *et al*., 2022). During certain seasonal behaviours, such as when feeding, their high-speed chases and surface activities, like breaching and lunge feeding, become apparent and can also help observers identify them in the wild (Babalola *et al*., 2021).

It's important to differentiate between the two recognized subspecies, *B. e. edeni* (the inshore form) and *B. e. brydei* (the offshore form). Research has indicated that these subspecies may exhibit slight morphological variations and ecological adaptations tailored to their respective environments, which can further aid in identification. For instance, *B. e. edeni* tends to be smaller and is often found in coastal regions, while *B. e. brydei* is typically larger and prefers deeper offshore waters (Babalola *et al*., 2021; Ferreira *et al*., 2021). Furthermore, variations in vocalizations between these two groups have also been noted, with each subspecies having unique acoustic patterns corresponding to their foraging and social behaviors (Wang *et al*., 2022; Viloria-Gómora*et al*., 2015).

Advancements in modern technology provide new dimensions for identifying Bryde's whales and understanding their ecology. Acoustic monitoring is a primary method employed to study these whales in their marine habitats. By employing underwater microphones (hydrophones), researchers can detect and analyse vocalizations attributed to Bryde's whales. Specific call types, such as "Biotwang" calls, have been documented, revealing not just the presence of these whales but also insights into their social interactions and behaviours (Hodge *et al*., 2015; Allen *et al*., 2024; Zhang *et al*., 2023). Acoustic data allow for localization and movement tracking without the need for direct

visual observations, which is invaluable given the species' elusive nature.

Additionally, recent studies have utilized satellite tracking and telemetry, employing suction-cup tags to monitor dive profiles and foraging behaviours in Bryde's whales. This method, often used in tandem with acoustic monitoring, provides a comprehensive overview of the whales' ecological interactions and sites favoured for feeding (Dong *et al*., 2022; Liu *et al*., 2021). The combination of these technologies is increasingly being used to assess distribution patterns, movements, and potential impacts from anthropogenic activities (Farrag *et al*. 2022; Zhang *et al*., 2021; 2023). Molecular techniques, including DNA barcoding and genetic analyses, have become essential tools for identifying Bryde's whales, particularly in cases where external morphological characteristics might be insufficient for differentiation (Rosel *et al*., 2021; Rosel and Wilcox 2014). For instance, genetic studies have confirmed the distinct lineages within the Bryde's whale complex, helping to delineate between subspecies and inform conservation strategies (Rosel and Wilcox 2014; Pastene *et al*., 2015).

Migration. The migration patterns of Bryde's whales are complex and differ between populations. Understanding these patterns is crucial for their conservation and management. Bryde's whales are generally considered less migratory compared to other baleen whale species, often exhibiting more localized movements related to prey availability and environmental conditions (Boer, 2010; Zhang *et al*., 2023).

Studies suggest that the offshore form of Bryde's whales may migrate seasonally between South Africa and Gabon, with movements observed from January to February and from May to July, respectively (Boer, 2010). This pattern indicates that while Bryde's whales do undertake some migrations, these are typically not long-distance like those seen in other baleen whale species. In contrast, inshore populations often remain resident year-round within their habitats (Purdon *et al*., 2020). In the Gulf of Mexico, Bryde's whales have been documented as year-round residents, indicating minimal migration or seasonal movements. This population is known to remain within a confined area, complicating the understanding of their migratory behaviours (Zhang *et al*., 2023). However, observations indicate that some Bryde's whales may exhibit movements during seasonal changes, particularly between feeding and breeding grounds (Salvadeo *et al*., 2011). Research around Weizhou Island in the Beibu Gulf, China, has demonstrated that Bryde's whales exhibit spatial–temporal connectivity with prey distribution, suggesting that mobility may depend more on foraging opportunities than on a classic migratory pattern seen in other cetacean species (Zhang *et al*., 2023). Seasonal factors influencing ocean currents and fish distribution could lead to localized migrations within certain areas rather than long-distance travel. Populations in different regions exhibit varying patterns. For example, Bryde's whales in the northeastern Atlantic show some degree of site fidelity, while those in southern Africa have been reported to migrate between populations with distinct seasonal movements (Ferreira *et al*., 2021; Rasmussen and Palacios, 2023). These differences underscore the need for localized conservation strategies tailored to specific populations and their migratory habits.

Threats and Conservation status. Bryde's whales face a myriad of threats in their natural habitats, compounded by their ecological vulnerabilities. Understanding the current conservation status and identifying the primary threats are essential to ensure their survival and promote effective management strategies.

One of the most significant threats to Bryde's whales is vessel strikes. These incidents are particularly concerning for populations in confined or busy shipping lanes, such as the Gulf of Mexico, where Bryde's whales are resident (Soldevilla *et al*., 2017). A study noted that the population in the Gulf of Mexico is critically small, which heightens the risks associated with such collisions (Soldevilla *et al*., 2017). Targeted conservation measures, including predictive modeling and spatial analysis, have been suggested to mitigate the impact of ship traffic on Bryde's whale habitats (Nanayakkara and Herath, 2017). Bryde's whales are frequently at risk due to entanglement in fishing gear and competition with fisheries for prey. The species often inhabits areas with high fishing activity, which increases the likelihood of unwanted interactions (Soldevilla *et al*., 2017). The resultant fishing gear traps can lead to serious injuries or fatalities, making this a significant conservation concern. Addressing this issue involves collaborating with local fisheries to develop mitigation strategies and reduce incidental catch of Bryde's whales (Segre *et al*., 2022). Increasing levels of anthropogenic noise from shipping, industrial activities, and recreational boating can adversely affect the communication and feeding behaviours of Bryde's whales (Wang *et al*., 2022). Noise pollution impairs their ability to detect prey and communicate effectively, potentially leading to decreased reproductive success and increased mortality rates. Regulations surrounding vessel operations in critical habitats may help alleviate this threat, ensuring whales can thrive in quieter environments (Putland *et al*., 2017). Recent findings have indicated that Bryde's whales may ingest marine debris, including plastics, which can have dire implications for their health (Abreo *et al*., 2023). Ingestion of foreign materials can affect the digestive system and overall fitness of these animals. Continuous monitoring and regulation of marine litter can play a role in mitigating this issue. Climate change poses an overarching threat to Bryde's whales by altering ocean temperatures and prey availability. Changes in water temperature have been linked to shifting prey distributions; therefore, Bryde's whales may struggle to hunt effectively as their traditional prey becomes scarcer or moves to different areas (Izadi *et al*., 2022). This challenge is particularly acute in regions affected by significant climatic events, affecting the whales' migratory patterns and overall survival rates. Understanding the migratory behaviours of Bryde's whales is essential in light of the many threats they face, including habitat degradation, human interference, and climate change impacts on prey availability (Farrag

et al., 2022; Frisch-Jordán and López-Arzate, 2024). As Bryde's whales adapt to varying ecological conditions, conservation measures must account for their non-migratory tendencies and localized movements, ensuring that critical habitats and migration corridors are protected (Díaz-Delgado *et al*., 2020). By monitoring their movements through advanced techniques like satellite tracking and passive acoustic monitoring, researchers can gain deeper insights into the driving factors behind their migration patterns and adapt conservation strategies accordingly (Farrag *et al*., 2022).

Current Conservation Status. As per the latest assessments by the International Union for Conservation of Nature (IUCN), Bryde's whales are classified as "Least Concern," though specific populations, such as those in the northern Gulf of Mexico, are critically endangered with very low population estimates (Zhang *et al*., 2023). The lack of significant recent data on population sizes and dynamics for various populations complicates conservation efforts. Moreover, the genetic uniqueness of the Gulf of Mexico Bryde's whales further underscores the need for targeted management strategies for isolated populations (Rosel and Wilcox 2014). The establishment of marine protected areas (MPAs) in critical habitats, like the Beibu Gulf in China, aims to safeguard Bryde's whales against some of these threats, particularly from human activities like shipping and fishing (Zhang *et al*., 2023). The success of such efforts will rely on stringent enforcement of protective measures and ongoing research to monitor the efficacy of these initiatives.

Global Distribution. Bryde's whales exhibit a widespread distribution that spans several ocean basins, including the Atlantic, Pacific, and Indian Oceans. Their habitat preference includes warm-temperate and tropical waters, where they show adaptability to both coastal and offshore environments (Boer, 2010; Maciel *et al*., 2016; Frisch-Jordán and López-Arzate 2024). Understanding their global distribution is essential for effective conservation strategies, particularly as certain populations face various threats.

Atlantic Ocean: Bryde's whales are commonly found along the eastern coast of South America, particularly in Brazil, where they are associated with abundant fish populations, such as sardines (Maciel *et al*., 2016; Siciliano *et al*., 2004). Their presence has been recorded from the northeastern regions down to southeastern Brazil and increasingly along the southern coastline, including the Cabo Frio region, which serves as a feeding ground (Maciel *et al*., 2016; Siciliano *et al*., 2004). Bryde's whales have also been sighted off the coast of Angola and western Africa, where their occurrence parallels warm-water currents (Ferreira *et al*., 2021).

Pacific Ocean: In the Pacific, they have been documented along the coast of California, with established populations reported in regions such as the Gulf of California and the Hauraki Gulf in New Zealand. They display a preference for continental shelf areas, often associated with abundant prey availability throughout the year (Weir, 2023; Rosel *et al*., 2021; Penry *et al*., 2018). Observations in the Pacific indicate that Bryde's whales benefit from local upwellings and other oceanographic features that enhance food resources (Figueiredo *et al*., 2015).

Indian Ocean: Bryde's whales have been recorded in the Indian Ocean, including sightings around the Maldives, providing evidence of their adaptability and wide range in tropical waters (Zhang *et al*., 2023; Díaz-Delgado *et al*., 2020). Their occurrence is particularly notable during certain oceanographic events, such as the El Niño Southern Oscillation, which can influence their distribution and abundance (Zhang *et al*., 2021).

Gulf of Mexico: This area represents a unique habitat due to the year-round residence of Bryde's whales, marking them as the only baleen whale species in the region. Genetic studies have identified a distinct lineage of Bryde's whales in the northern Gulf of Mexico, underscoring the importance of localized conservation efforts (Purdon *et al*., 2020; Gonçalves *et al*., 2015). Their restricted distribution and small population size increase vulnerability to anthropogenic threats, such as vessel traffic and fisheries interactions (Steiner *et al*., 2008).

Indian distribution. Bryde's whales are distributed widely across various oceanic regions. While specific studies directly focused on their presence in Indian waters are limited, broader surveys and sightings have provided valuable insights into their distribution patterns within the Indian Ocean, particularly along the coasts of India.

Spatial Distribution

While more specific sighting numbers and studies in India are less documented compared to other regions, Bryde's whales are likely to inhabit areas with plentiful prey resources. This is indicative of their opportunistic foraging behavior, particularly in areas associated with local fishing activities (Cerchio *et al*., 2015; Izadi *et al*., 2022).

Coastal Sightings. Bryde's whales (*B. edeni/brydei*) have been recorded from various parts of the Indian coastline, particularly within the Bay of Bengal and the Arabian Sea, both of which are characterized by high productivity and dynamic trophic conditions. These regions, influenced by monsoonal upwelling and nutrient enrichment, provide favorable habitats for pelagic fishes and cephalopods, prey resources that attract baleen whales (Smith *et al*., 2023).

Historical documentation indicates that Bryde's whales have been present in Indian waters for several decades. Table 1 summarizes the early records of sightings and strandings across different parts of the Indian coastline. The earliest record dates to 1979 from the west coast of India (Lal Mohan, 1992), followed by a 1981 sighting from the Bay of Bengal (De Silva, 1987), and a 1983 stranding in the Gulf of Mannar (Lal Mohan, 1992). Subsequent sightings in the Tamil Nadu/Sri Lanka sector (1984) reported nine individuals (De Silva, 1987), suggesting an active population utilizing the southeastern coast. The latest of the early records comes from Point Calimere on India's east coast in 2000, also involving a stranded whale (Sathasivam, 2002).

The spatial distribution of these records indicates a broad geographic range covering both coastal and nearshore habitats. The presence of multiple sightings in the Tamil Nadu–Sri Lanka sector highlights the potential for a recurring population in the southeastern waters, likely supported by the productive upwelling zones of the Gulf of Mannar and Palk Bay.

Subsequent reports since 2015 have reinforced the continued presence of Bryde's whales in Indian waters. On the western coast, a 12 m whale stranded on Mumbai's beach in January 2016 and drew national attention. A similar event in Ratnagiri, Maharashtra (2015) involved a 16 m individual. On the eastern coast, a 6.9 m whale carcass was found at Kanathur Reddykuppam, Chennai (2015), while another stranding occurred near the Thoothukudi Thermal Power Plant, Tamil Nadu (July 2016). Fisher communities and marine researchers attributed these incidents to potential navigational errors, attraction to thermal discharges, internal organ malfunction, injury from reefs, or ecological behaviors such as breeding and prey pursuit.

The 2017 report by Sutaria *et al.* (2017) to the International Whaling Commission (*Baleen Whale Records from India*) verified Bryde's whales among the baleen whales recorded from Indian waters, emphasizing their occurrence in productive marine zones such as the Arabian Sea, Bay of Bengal, and the Andaman and Nicobar Islands. The species, though less frequently observed than dolphins or other odontocetes, appears regularly across India's coasts, albeit often recorded post-mortem through stranding events.

The first live sighting of a Bryde's whale from Odisha waters was reported by Sudhan *et al.* (2017). The observation, accompanied by behavioral notes, marked a significant record for India's eastern seaboard. The authors highlighted the presence of a closely related Bryde's whale population off Bangladesh, suggesting transboundary distribution within the northern Bay of Bengal.

Further insight into regional patterns comes from Patro *et al.* (2022), who compiled data from beach surveys, citizen reports, and field investigations between 2016 and 2020. The study documented 18 instances of whale strandings along the Odisha coast, of which 12 (66.6%) were baleen whales and 11 (61%) specifically Bryde's whales. The majority (91%) of these events occurred during the post-monsoon season (November–February), coinciding with heightened coastal productivity and prey abundance. This temporal clustering supports the hypothesis that Bryde's whales migrate seasonally toward the northwestern Bay of Bengal for feeding purposes.

The findings correspond with the species' known ecological range between 40° N and 40° S, and their preference for warm, productive waters. However, the study also noted that stranding data alone cannot conclusively establish feeding grounds or residency. Complementary approaches such as stomach content analysis, stable isotope studies, and direct observation of foraging behaviour were suggested to confirm the purpose of these seasonal congregations.

Bryde's whale presence along the northeastern coast of India has been increasingly recognized in recent years. A notable case occurred near Lakshmipur village, West Bengal (Sundarbans region), where a juvenile Bryde's whale was found stranded and later rescued by forest officials and villagers in a coordinated operation involving over forty individuals. This marks the fourth documented sighting in West Bengal, reinforcing the likelihood of a small resident or recurrent population in this region.

The Swatch of No Ground, a deep submarine canyon located off the Sundarbans, is known for its exceptional marine biodiversity and has been proposed as a key habitat for cetaceans. The repeated occurrence of Bryde's whales near this canyon suggests that it may serve as a foraging or nursery area. Reports from the region (Times of India, 2025) note that these whales typically inhabit warm, shelf-slope environments but face increasing anthropogenic threats such as vessel strikes, fishing net entanglement, and underwater noise pollution.

The compiled evidence from the western, eastern, and northeastern coasts reveals that Indian waters serve multiple ecological functions for Bryde's whales, including potential feeding and migratory corridors. Their repeated strandings along the Odisha and Tamil Nadu coasts, coupled with sporadic sightings in the Arabian Sea and the Bay of Bengal, suggest a broad distribution influenced by regional oceanographic conditions. The post-monsoon productivity peaks, driven by nutrient inflow and plankton blooms, appear to coincide with increased whale presence, likely linked to prey availability.

Bryde's whales are known for their preference for offshore and slope waters, yet their periodic movement into coastal areas increases the risk of human interaction. Industrial development and coastal infrastructure, especially in states such as Tamil Nadu, Odisha, and Maharashtra, have expanded near critical habitats. The stranding at Thoothukudi Thermal Power Plant exemplifies how thermal discharges and altered water temperatures can disorient cetaceans, leading them toward shallow areas. Additionally, intensive fishing operations in nearshore waters increase the likelihood of entanglement, while the growing density of shipping lanes heightens the risk of vessel collisions.

Despite these risks, the consistent pattern of records over the past four decades suggests that Bryde's whales are regular, albeit elusive, components of India's marine fauna. The mix of historical data (1979–2000) and recent reports (2015–2025) demonstrates continuity in distribution and possibly stable, localized subpopulations. However, the relatively low number of live sightings compared to strandings indicates limited surface activity near coastal observation zones or insufficient systematic monitoring.

Therefore, it can be said that Bryde's whales have been observed or stranded along almost the entire Indian coastline, from the west coast (Maharashtra, Gujarat) to the east coast (Odisha, Tamil Nadu, West Bengal) and island regions (Andaman and Nicobar). Historical records from Lal Mohan (1992); De Silva (1987); Sathasivam (2002) establish a baseline of distribution,

while more recent studies by Sutaria *et al.* (2017); Sudhan *et al.* (2017); Patro *et al.* (2022), and field observations reported in the *Times of India* (2025) confirm their continued occurrence. The concentration of strandings during the post-monsoon months aligns with ocean productivity cycles, supporting hypotheses of seasonal migration for feeding.

Collectively, these observations affirm that Indian coastal waters form part of the broader Indo-Pacific range of *Balaenoptera edeni/brydei*. The available evidence, integrating historical, stranding, and live-sighting data, strongly indicates that Bryde's whales are recurrent visitors and possibly maintain small resident populations in specific productive regions such as the Gulf of Mannar, Odisha coast, and Swatch of No Ground in the Bay of Bengal.

Conservation and Research Needs. Efforts to monitor Bryde's whales in Indian waters are essential for understanding their distribution and ensuring their conservation. As marine life in the Indian Ocean faces increasing threats, including habitat degradation and entanglement risks from fishing activities, there is a critical need for targeted studies to assess the populations of Bryde's whales and their habitat preferences in India (Zhang *et al.*, 2021). More structured research, including sighting surveys and community-based observation initiatives, could significantly enhance our understanding of Bryde's whale distribution, movements, and interactions with human activities in this region. Their elusive nature and sporadic sighting success make such efforts imperative for effective conservation outcomes.

Table 1: Report on occurrence of Bryde's whale at Indian coast.

Location	Number	Year	Remarks	Citation
Dhanushkodi, Tamil Nadu	1	1973	Stranding	Sudhan *et al.* (2017)
Beypore, Calicut, Kerala	1	1979	Stranding	Sudhan *et al.* (2017)
West coast of India	1	1979	Stranding	Lal Mohan (1992)
Bay of Bengal	1	1981	Sighting	De Silva (1987)
Gulf of Mannar	1	1983	Stranding	Lal Mohan (1992)
Tamil Nadu/Srilanka	9	1984	Sighting	De Silva (1987)
Point Calimere, east coast of India	1	2000	Stranding	Sathasivam (2002)
Tamilnadu	1	2003	Stranding	Sutaria *et al.* (2017)
Gulf of Mannar	1	2006	Stranding	Jayasankar *et al.* (2006)
Rushikulya River, Odisha,	1	2007	Stranding	John *et al.* (2012)
Edayar, Thiruvananthapuram, Kerala	1	2009	Stranding	Sudhan *et al*. (2017)
Rushikulya River mouth, southern Odisha	3	2009	Sighting	John *et al.* (2012)
Gulf of Mannar	1	2009	Stranding	Jayasankar *et al*. 2009)
Near Gopalpur light house, Odisha	1	2010	Stranding	John *et al.* (2012)
Kadmat island, Lakshadweep	1	2010	Stranding	Sudhan *et al*. (2017)
Thiruvananthapuram coast	1	2011	Stranding	George *et al.* 2011)
Digha, West Bengal	1	2012	Dead	TNIE (2017)
Tamilnadu	1	2012	Stranding	Sutaria *et al.* (2017)
Poonthura beach, Kerala	1	2012	Stranding	Sutaria *et al.* (2017)
Offshore Karwar, Karnataka	1	2015	Sighting	Jamalabad (2015)
Tamilnadu	1	2015	Stranding	Sutaria *et al.* (2017)
Mumbai	1	2016	Dead	Limaye (2016)
Lakshadweep	1	2016	Stranding	Sutaria *et al.* (2017)
Kerala	1	2016	Stranding	Sutaria *et al.* (2017)
Goa	1	2016	Stranding	Sutaria *et al.* (2017)
Maharashtra	3	2016	Stranding	Sutaria *et al.* (2017)
Gujarat	2	2016	Stranding	Sutaria *et al.* (2017)
Tamilnadu	1	2016	Stranding	Sutaria *et al.* (2017)
Puri,Orissa	1	2016	Stranding	Sutaria *et al.* (2017)
Murud beach in Ratnagiri	1	2020	Dead	Bhalerao (2020)
Berhampur, Odisha	1	2021	Dead	PTI (2021)
Veli, Thiruvananthapuram	1	2022	Dead	Special Correspondent (2022)
Srikakulam, Andhra Pradesh	1	2023	Dead	Ganguly (2023)
Kasarkod Tonka near Honnavar in Uttara Kannada	1	2023	Dead	Kumar (2023)
Kakdwip, West Bengal	1	2025	Stranding	Mukherjee (2025)

Fig. 1. Bryde's whale rescued from Kakdwip, West Bengal, India on 2nd January, 2024 (Image courtesy: Indianexpress.com, https://indianexpress.com/article/cities/kolkata/whale-carcass-sagar-islands-resemblance-rescued-released-9762128/)

CONCLUSIONS

The status of Bryde's whales (*B. edeni*) in Indian waters remains a subject of concern due to the limited understanding of their distribution, population dynamics, and the threats they face. While sightings of Bryde's whales have been recorded along the coast of India, particularly in regions such as the Bay of Bengal and the Arabian Sea, comprehensive research focusing on their habitats and behaviors is still lacking (Afsal *et al*., 2023). The presence of Bryde's whales in Indian waters underscores the necessity for heightened conservation efforts, particularly since these waters can be subject to high levels of anthropogenic activity, including fishing and shipping.

Bryde's whales inhabit warm-temperate and tropical waters, with their distribution linked closely to the availability of prey, primarily small pelagic fish such as sardines and anchovies (Constantine *et al*., 2018; Afsal *et al*., 2023). The dynamic interactions between these whales and their marine environment are likely influenced by ecological factors such as ocean currents and seasonal fluctuations in prey availability. This necessitates an understanding of local environmental conditions, such as the effects of climate change on fish populations, to anticipate how Bryde's whales may adapt or be affected (Ferreira *et al*., 2021).

Conservation strategies for Bryde's whales in India must consider the multifaceted threats they face, including vessel strikes, fishing gear entanglements, and noise pollution from maritime activities. Implementing protective measures, such as establishing marine protected areas (MPAs) and promoting responsible fishing practices, can create safe habitats for these whales and minimize potential threats (Zhang *et al*., 2023; Afsal *et al*., 2023). Additionally, fostering collaboration between local communities and researchers can enhance conservation awareness and implement monitoring programs that contribute to the sustainable management of marine resources (Rosel *et al*., 2021).

In conclusion, the conservation status of Bryde's whales in India is precarious due to insufficient data on their distribution and the increasing threats from human

activities. Establishing dedicated conservation efforts, enhancing research, and promoting awareness regarding Bryde's whales are critical steps toward ensuring the survival of this species within Indian waters. Such efforts will not only benefit Bryde's whales but will also contribute to the overall health and diversity of marine ecosystems in the region.

FUTURE SCOPE

Future research on Bryde's whales in Indian waters should emphasize long-term, systematic monitoring to better understand their population size, structure, and spatial ecology. Integrating passive acoustic monitoring, satellite telemetry, photo-identification, and genetic analyses will help clarify residency patterns, migratory connectivity, and taxonomic status of regional populations. Detailed studies on prey availability, trophic interactions, and oceanographic drivers, particularly during the post-monsoon period, are needed to explain seasonal occurrence and potential feeding grounds. Strengthening coordinated stranding response programs, along with stable isotope, contaminant, and health assessments, will provide insights into anthropogenic pressures such as fisheries interactions, vessel strikes, noise, and pollution. These scientific findings should be translated into evidence-based management actions, including identification of critical habitats, establishment of marine protected areas, and stakeholder-driven mitigation strategies, to ensure the long-term conservation of Bryde's whales in Indian waters.

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