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# Distribution and Abundance of the Blue Whale (*Balaenoptera musculus indica*) off Sri Lanka during the Southwest Monsoon 2018

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**Abstract:** Blue whales *Balaenoptera musculus* are the most abundant and widely distributed cetacean species in Sri Lankan waters. A vessel-based opportunistic line transect survey focusing on marine mammals was conducted in Sri Lankan waters between 24 June to 12 July 2018, while an ecosystem survey was performed by the R/V Dr. Fridtjof Nansen. The entire transect length was 2090 km within an area of 3895 km$^2$. Overall, 72% (n = 57) of blue whale observations were group assemblages ranging between 1 and 5 individuals out of a total of 79 sightings. The largest aggregations of blue whales were recorded at the intersection of the submarine canyon off the coastline of Mirissa and busy shipping lanes between Dondra Head and Galle, where previous ship strikes were recorded. Overall, the average observed group size was 2.64 (CV, 12.34%; 95% CI, 2.07–3.38), the average group density was 0.0029 km$^{-2}$ (CV, 35.96%; 95% CI, 0.00145–0.00610), and the total blue whale abundance within the survey area was 513 individuals (CV, 38.02%; 95% CI, 243–1083). These survey results fill vital knowledge gaps regarding the abundance and distribution of blue whales in Sri Lanka, which is essential for the establishment of management and conservation strategies.

**Keywords:** blue whale; *Balaenoptera musculus*; distribution; abundance; ship strikes; Sri Lanka



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## 1. Introduction

The blue whale has been reported as the most frequently encountered large cetacean species in the Northern Indian Ocean (NIO) [1,2]. The spatial and temporal occurrence of this species in some areas of Sri Lankan waters is well documented [3–6]; however, little is known about their total abundance, distribution and migration patterns [7].

The International Union for Conservation of Nature (IUCN) "Red List of Threatened species-2020" has categorized the blue whales in the NIO as "not assessed" and the population trend as "not specified" [8]. Globally, the blue whale has been categorized as "endangered", with populations that were subjected to heavy commercial exploitation during the whaling era still far below the initial abundance levels [9]. In some areas, such as around South Georgia, recovery has been slow [10], but globally, the population trend is assessed as "increasing" [9,11]. The NIO blue whales were not as heavily exploited as in the Antarctic region, although they were subject to whaling in waters off Somalia, Maldives, Sri Lanka and Oman [2,12,13]. Recently, there are indications that the NIO population may have been increasing gradually [14].

Blue whales are found in the Arabian Sea [2,15,16]; however, no records are known from the Bay of Bengal [17,18] except from the east coast of Sri Lanka [3,16,19]. Two subspecies of blue whales (Pygmy blue whale, *Balaenoptera musculus brevicauda*, and the

Indian Ocean blue whale, *B. m. indica)* have been described in the NIO, but the taxonomy remains uncertain [16,20]. These are residents of the tropical warm waters of the Indian Ocean throughout the year [21,22]. Acoustic studies have indicated that the Sri Lankan subpopulation is geographically isolated [2,3,22,23], and a recent study shows that multiple pygmy blue whale acoustic populations are found in the Indian Ocean [24]. However, the classification of these two subspecies is problematic, as they do not display distinct morphological and behavioral differences. The International Whaling Commission Scientific Committee [25] has noted that blue whales in the Indian Ocean are distinguished primarily by song type and occur in the northwest Indian Ocean (Oman song type), central Indian Ocean (Sri Lankan song type), southwest Indian Ocean (Madagascar to Kerguelen), and southeastern Indian Ocean (Australia to Indonesia).

The length frequency data of the illegal Soviet whaling fleet operating in the Arabian Sea close to the Maldives and Sri Lanka showed a significant difference in the length at maturity of the Indian Ocean blue whales (0.5–0.6 m smaller) from that of the pygmy type. Hence, the smaller blue whale found around Sri Lanka and the Maldives has been classified as the Indian Ocean blue whale [26].

Lethal and nonlethal injuries to blue whales and other larger cetaceans are well documented and common in the southern waters of Sri Lanka [6,12]. Randage et al. [5] recorded four large whale strandings within five months period in 2014, showing a high rate of strandings in Sri Lankan waters. Of these, two deaths were confirmed as ship strikes. Further, Nanayakkara et al. [27] confirmed fourteen ship strikes on larger whales during the period from 2010 to 2012, including 13 incidents around the south and west coasts of Sri Lanka.

The south and southwest coastal upwelling areas off of Sri Lanka are rich in phytoplankton and zooplankton biomass [28]. One of the prominent whale aggregations occurs along the continental shelf break in the Sri Lankan southern upwelling region, which is rich in their main food sources, sergestid shrimp and euphausiids (krill) [29,30]. These aggregations, at the narrowest continental shelf off Dondra to Galle, coincide with one of the most trafficked shipping lanes in South Asia, and consequently, the whales are prone to ship strikes [5,6,12,31]. The studies on blue whales around Sri Lanka have been conducted at various temporal and spatial scales. However, until the present study, no previous single survey has covered the entire coast of Sri Lanka to document the distribution and abundance of blue whales. The objective of the present study was to gather information on the distribution and abundance of blue whales in Sri Lankan waters to address known threats such as ship strikes on whales, acoustic pollution, fisheries interactions, maritime accidents, etc.

## 2. Materials and Methods

An opportunistic survey on blue whales was conducted during the ecosystem survey carried out by the R/V *Dr Fridtjof Nansen* from 24 June to 12 July 2018 around Sri Lanka (between latitudes 5°24′ and 10°23′ N and longitudes 78°55′ and 82°25′ E), during the southwest monsoon. The perpendicular ecosystem line-transects alternatively varied from 40 to 100 km, while water depth at the offshore end of the transect varied from 1000 m to 1500 m, respectively. Whale observations were made on perpendicular transects and during their transits in day times, except when oceanographic stations are occupied. In addition, two dedicated line transects, parallel to the eastern and southwestern coasts, which were well-known whale aggregation sites [3–6], were surveyed. The total length of all surveyed transects was 2090 km within a survey area of 3895 km$^2$ (Figure 1). The survey area encompassed the water area between the 20 and 1000 m isobaths.

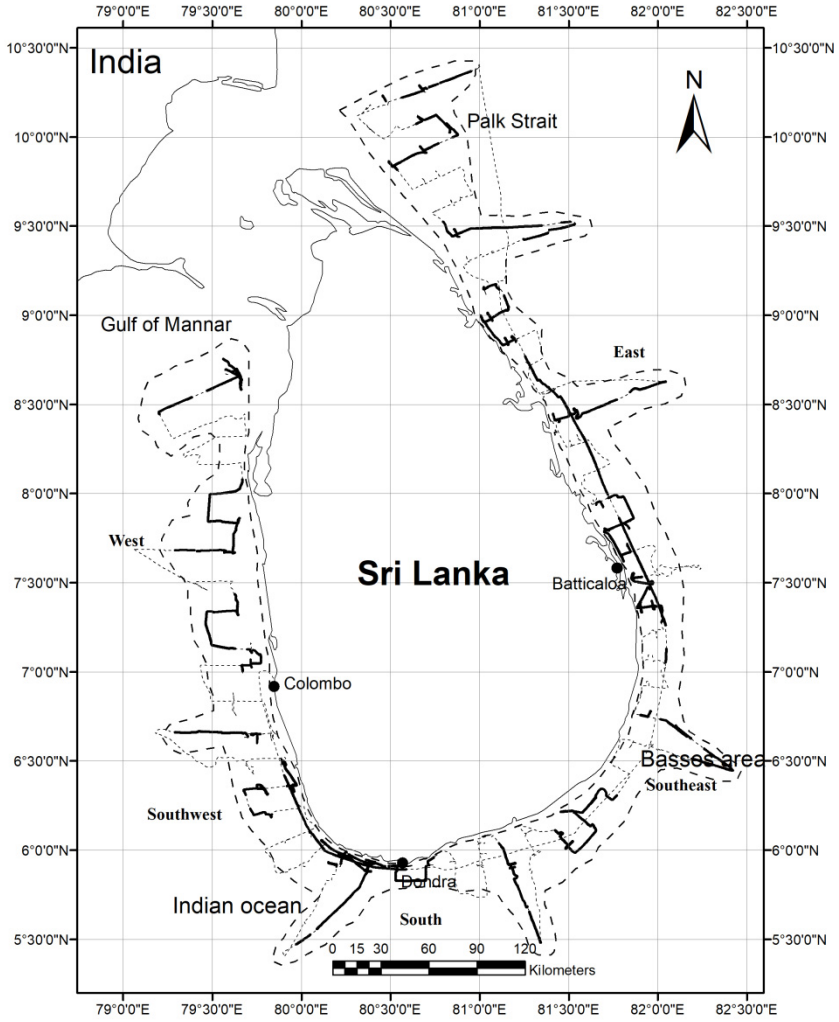



**Figure 1.** Survey area and line-transect of the R/V Dr. Fridtjof Nansen ecosystem survey (2018). The dashed line indicates the survey area, dotted line is the survey line transect and thick black line indicates the marine mammal survey track.

A dedicated marine mammal observer was stationed on the bird and marine mammal observatory at a height of 22 m and scanned approximately 180° ahead of the vessel with the naked eye. Nikon 7 × 50 hand-held reticule binoculars were used to determine the species and orientation of the animal relative to the vessel. Observations were carried out during the daytime from 6.00 to 18.00 but suspended when the vessel diverted from the transect or stopped to carry out oceanographic profiling. Oceanographic and trawling stations were assigned based on depth; thus, navigation time between stations varied widely (1–2 h). The survey was performed on a Beaufort sea scale below 5, and the average speed of the vessel was 8–10 knots. All observations were conducted in passing mode, and the vessel never stopped or turned to identify species or individuals or estimate group size when sightings occurred.

Although most of the effort was undertaken by a single observer, fatigue was managed by taking breaks during oceanographic sampling. The captain and other scientific staff also undertook observations and provided assistance when sightings occurred, particularly with estimating group size, which allowed the primary observer to continue searching. If a group of whales was dispersed, the distance was estimated to the midpoint of the group. Distances to sightings were estimated by eye, and distance training was conducted throughout the survey whenever a visual estimate of a suitable target (other vessels,

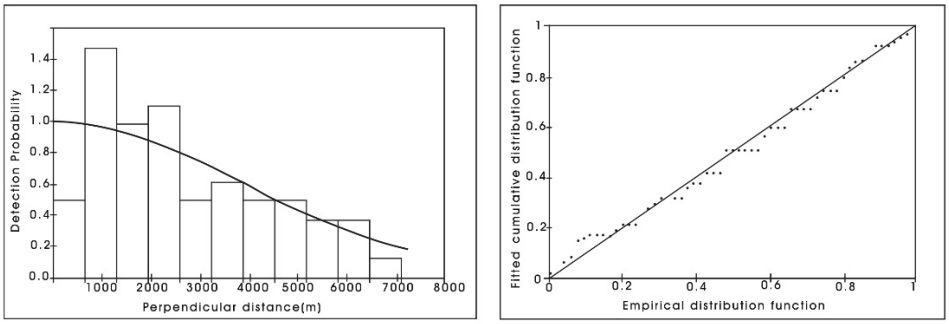
landmarks or lighthouses) could be cross-checked with the radar system of the ship through communication with the vessel officers on the bridge.

Blue whales were identified based on a combination of body size, shape of the dorsal fin and characteristics of the blow. Blue whales off Sri Lanka frequently fluke up while diving, which allows them to be distinguished from other baleen whale species (such as Bryde's whale, which is the second most frequently reported baleen whale species around Sri Lanka) at greater distances [7]. Photographs of the sightings were also taken using a Nikon D 500 digital camera with a 70–300 mm telephoto lens for individual identification or to confirm species.

The density of blue whales was estimated using a Conventional Distance Sampling (CDS) approach implemented in Programme Distance 7.2 release 1 [32]. The probability of detection for a whale directly on the track line (often referred to as g(0)) was assumed to be one. Simulation studies based on telemetry data on surfacing rates of blue whales off Sri Lanka [33] have estimated g(0) for blue whales for a single observer of between 0.75 and 0.95, depending on vessel speed [34]. The combination of vessel speeds of 8–10 knots and a larger effective strip width than assumed by Leaper et al. [34] suggests that g(0) would be expected to be greater than 0.8. This assumption is consistent with other blue whale surveys, e.g., [2,6,35].

## 3. Results

The distribution of perpendicular distances to blue whales is shown in Figure 2a. A half-normal key model with cosine adjustments was selected as the best model for detection probability with distance (Figure 2a), which had a lower AIC (ΔAIC = 2.13) compared to a half-normal key without adjustments or other key functions. Uniform and hazard-rate key functions with simple polynomial and cosine adjustments were also used as other models. The data were right truncated to 7200 m to remove the outliers. The diagnostic quantile plot shown in Figure 2b and further tests to investigate any trends in the residuals with distance (Kolmogorov–Smirnov test, $p = 0.83$) showed an acceptable fit. Detection in the first interval (0–652 m) was substantially low, possibly due to the invisibility of the ship's close proximity to the elevated observation platform and the deployment of a single observer. Based on this detection function, the estimated effective strip width was 4567 m (CV, 11.3%; 95% CI, 3642–5725).




(**a**) (**b**)

**Figure 2.** (**a**) Histogram of perpendicular sighting distances and the fitted detection function for the best fitting model; CDS half-normal model with cosine adjustment. (**b**) QQ plot fitted empirical distribution function against cumulative distribution function.

The survey started at the northeast of the Exclusive Economic Zone (EEZ) of Sri Lanka, close to the border with India, and continued around Sri Lanka following the survey tracks shown in Figure 1 until the vessel reached the Gulf of Mannar. During the survey, five species of cetacean, i.e., blue whale, Bryde's whale, spinner dolphin, short-finned pilot whale and melon-headed whale, were identified. Of these, blue whales were the most

frequently sighted cetacean species (*n* = 57 sightings of blue whale groups from 79 (72%) sightings of all cetaceans). The locations of blue whale sightings are shown in Figure 3.

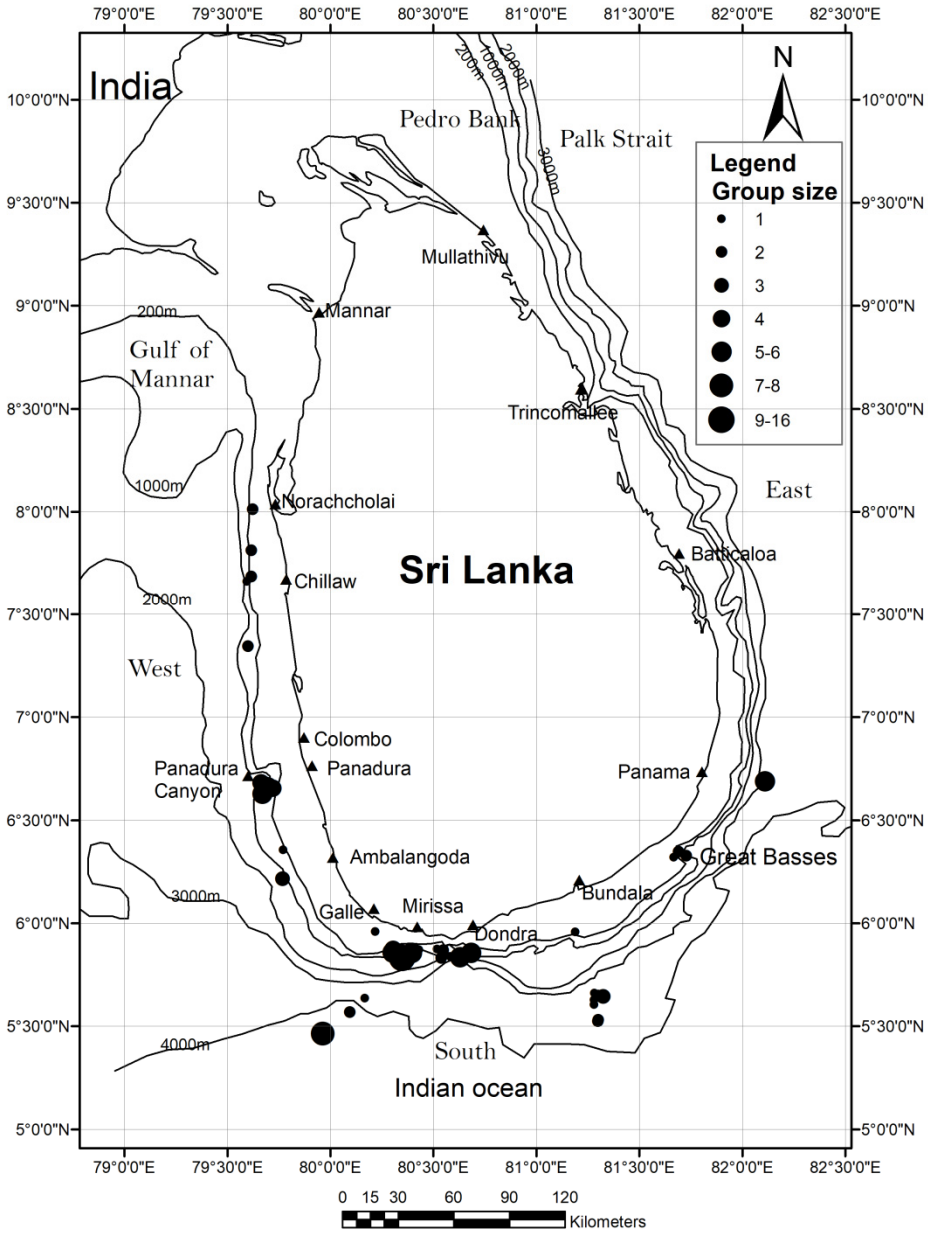



**Figure 3.** Locations where blue whales were sighted. Black lines are bathymetric contours.

The survey revealed that blue whale distribution and abundance were not uniform within the survey area (Figure 3). No blue whales were recorded in the Pedro Bank, where the Palk Straight meets the Bay of Bengal, in the northeast and eastern coastal regions, and the first sighting of a blue whale during the survey was recorded on a canyon in the southeastern region from off Panama to Little Basses reef (Figure 3). Thereafter, frequent sightings of groups of blue whales were observed at the margin of the continental shelf along the south coast, especially around the Dondra canyons. Sightings on the west coast were comparatively fewer than on the southern coast; however, aggregations of blue whales were recorded off the Panadura Canyon on the west coast, approximately 25 km off the coast. The number of sightings and group sizes gradually diminished towards the northwestern coast. Blue whale aggregations were most frequently observed at the edge of the continental shelf break along the 1000 m depth contour and on submarine canyons

scattered on the shelf. The width of the shelf to where depths drop from 100 m to 1000 m varies around Sri Lanka between 2 and 35 km from the coast.

Fifty-seven sightings of blue whale groups, with an estimated total of 151 individuals, were recorded during the survey. The mean group size was 2.64 (SE 0.326). The encounter rate (n/L) was 27.2 groups per 1000 km track length. Mean group size of the sightings and group density were, respectively, 2.64 (CV, 12.34%; 95% CI, 2.07–3.38; SE, 0.326) and 0.00298 $km^{-2}$ (CV, 35.96%; 95% CI, 0.00145–0.00610). During the southwest monsoon period, the estimated blue whale density was 0.00791 $km^{-2}$ (CV, 38.02%; 95% CI, 0.00374–0.0167), and abundance (N) of the survey area was 513 (CV, 38.02%; 95% CI, 243–1083). The estimated abundance, as per the g(0) values of 0.75 and 0.95, were, respectively, 385 and 487.

## 4. Discussion

Although blue whales are frequently sighted in the waters of Sri Lanka, knowledge of population status, migration and distribution patterns, which are required for effective conservation measures, is still limited [2,12]. Surveys of the full range of blue whales are logistically and technically difficult due to their wide range, seasonal movements, pelagic lifestyle and occurrence in the open ocean. Therefore, many surveys and research programs on blue whales undertaken in Sri Lanka have been limited in duration and confined to a small proportion of the overall distribution area, e.g., [3,5,6,14,29,31,36]. The survey results presented here covered the coastal and offshore waters (20 to 1000 m depth) of Sri Lanka, except for the shallow northern waters. The survey was conducted during the southwest monsoon period and has resulted in new information on the abundance and distribution of blue whales during the southwest monsoon season.

Concentrations of blue whales were mainly found off the south and west coasts, with no sightings made off the east coast north of Panama village (6°45′ N). Our survey covered a larger area than that of the R/V Odyssey voyage from March to June 2003, which covered a wide area of Sri Lankan waters except for the north and major parts of the east [4]. However, that survey reported only 9 groups of blue whales comprising 12 individuals [4]. The number of sightings from our survey was considerably higher than this, possibly due to the concentration of effort on the continental shelf area. In other areas, blue whale aggregations are also most common along the continental shelf and submarine canyons [37].

Several studies have reported blue whale occurrence off Trincomalee on the east coast of Sri Lanka, e.g., [1,3,19,38]. According to Nanayakkara et al. [19], the blue whale distribution on the east coast during the 1983–1984 period recorded three areas with dense blue whale aggregations within and near Trincomalee Bay, 10–30 km off Mullaitivu and 20 km off Batticaloa. Visual surveys, which were conducted in two successive years (5 February to 6 April 1983 and 3 March to 23 April 1984) in the inter-monsoon period, recorded a total of 87 sightings of blue whales with group sizes of 1–6 individuals, with the majority of them heading towards the south. In April 1984, all the whales that inhabited the front of Trincomalee Bay had migrated out of the survey area. Nanayakkara et al. [19] reported that the blue whale was the most frequently recorded baleen whale species off the Trincomalee coast between July 2010 and Jan 2012. During those surveys, peak sighting rates were recorded in May and June during the southwest monsoon period, with much lower densities in July. During the present survey (Figure 3), no sightings of whales were recorded in well-known blue whale habitats off Mullaitivu to Panama throughout the east coast, with a group of six blue whales 33 km east of Panama being the most northerly sighting off the east coast.

However, our survey was conducted during the period where there are upwellings induced by the southwest monsoon along the south and southwest coast [39], with higher biomass and density of zooplankton recorded along the south and west coasts than the east during the SW monsoon [28]. Hence, our results would be consistent with earlier studies of blue whales present along the north and east coasts, but they had already moved south.

We observed three sightings around the submarine canyon in the Little Basses area, southeast of Sri Lanka, which is an area where blue whales have been previously reported. De Silva [40] reported a few blue whale sightings and stranding while R/V Odyssey sighted a group with 5–6 individuals in the Little Basses area [4].

Dense aggregations of blue whales were observed from Dondra point to Galle on the continental shelf break, especially at a depth range of 500–2000 m. This was consistent with the results of the previous surveys in a survey area of 150 × 50 km, 30–47 km off of the southern coast of Sri Lanka (off Bundala to Galle) to assess the whale distribution in relation to the major shipping lanes [6]. Many studies have shown high levels of blue whale occurrence within this area; however, surveys during the southwest monsoon (SW) period are limited [6,14,41]. The present survey, conducted during the SW monsoon, also reveals a similar pattern of blue whale aggregations along the continental shelf off Dondra to Galle and their distribution towards the deep sea in the south. Russell et al. [42] reported concentrations of blue whales close to the southern coast during the SW monsoon period. Other studies have reported peak sighting rates of blue whales off the south coast of Sri Lanka in April [14,20], with a correspondingly high monthly carcass stranding frequency also reported during the April to July period [20].

The blue whale distribution pattern observed during the present study is consistent with observations made by Alling et al. [3] that whales migrate towards the southeast, south, and western coastal regions of Sri Lanka from the east coast after April. However, many studies indicate that the peak occurrence of blue whales off the south coast is during March and April [5,6,14]. Therefore, there is evidence that part of the NIO blue whale population utilizes waters surrounding Sri Lanka during the inter-monsoon period, and thereafter the majority aggregate off the southern, western, and southwestern coastal regions.

Since independent marine surveys are very costly, many researchers have used data available from opportunistic platforms collected by commercial whale-watching operators, which frequently operate during calm sea conditions or non-monsoonal seasons. Therefore, there is a data deficiency during the southwest monsoon (May to August) in the southern and western coastal regions due to the whale-watching operators and systematic surveys not being conducted under rough sea conditions. Our survey conducted during the middle of the SW monsoon season in June and July helps to fill this data gap.

Although cetaceans occur throughout the coastal waters of Sri Lanka, no estimates of total abundance are available for any of the commonly encountered whale species [36]. de Vos et al. [12] stated that the blue whale population is assumed to be growing; however, overall population growth is believed to be negatively affected by the mortalities caused by ship strikes and fisheries interactions. Our survey has provided the spatial distribution and abundance of blue whales around Sri Lanka during the southwest monsoon. Frequent sightings of blue whales were recorded from Dondra Head to Galle on the south coast. The south coast at the Dondra submarine canyon and the western areas of Sri Lanka are the coastal upwelling area in Sri Lanka coupled with higher zooplankton biomass [28] during the SW monsoon, where blue whales frequently aggregate for feeding. These aggregation sites coincide with the busiest shipping lanes in the NIO. With the expansion of the maritime transportation industry, ship strikes causing major injuries and deaths to whales remain a major hazard. Berman-Kowalewski et al. [43] reported that the impact on blue whales might be of greatest concern, given their smaller population, slow population recovery and high proportion of mortality. To estimate the impact of anthropogenic threats, including ship strikes and fisheries, knowledge of the blue whale population is very important [44]. Considering the findings of the current study and the high densities of whales in areas of heavy shipping traffic, the local authorities have to impose precautionary measures to avoid or reduce hazardous impacts on whales. Speed reduction, changing the course of the vessel, onboard observatory programs, avoidance of the area where whales are aggregating and supporting Apps and tools for providing information for the mariners are some of the tools that can be used. The abundance estimates from this study also provide valuable baseline information since the survey covered almost the entirety of the waters around Sri Lanka.

Table 1 provides an overview of existing blue whale population studies in different world regions to compare with the results from the present study. The first blue whale abundance estimates in Sri Lanka were for the south coast (off Bundala to Galle) during the northeast and inter-monsoon periods of the year 2014 to 2015, where blue whales were frequently aggregated in large groups [6]. They estimated an abundance of 270 blue whales within a relatively small area off the south coast, but previous studies suggest these surveys were conducted during the period when the peak blue whale occurrence would be expected within this region. The density of blue whales off the south coast estimated by Priyadarshana et al. [6] of 0.036 whales/km$^2$ is 4.6 times higher than the density estimated by the current study for Sri Lankan waters as a whole. This is consistent with the south coast being an important area for blue whales throughout the year. The group size reported in this study was greater than that in Priyardashana et al. [6], but so was the estimated strip width. The higher estimated strip width in this study would be expected because of the much higher observation platform (22 m compared to 4 m). The smaller distances at which whales were observed in the study by Priyadarshana et al. [6] made it easier to record sightings of individuals rather than groups, which probably explains the difference in recorded group size.

**Table 1.** Comparison of blue whale population studies in Sri Lanka (NIO) and other parts of the world.

| Source | Area | Density Whales/km$^2$ | Mean Group Size | Encounter Rate (per 1000 km Length of Transect) |
|---|---|---|---|---|
| Priyadarshana et al. [6] | Sri Lanka (south) (NIO) | 0.03600 | 1.46 | 59.00 |
| Ballance and Pitman [45] | Western Indian Ocean (WIO) | - | 1.60 | 1.93 |
| Calambokidis and Barlow [35] | North Pacific Ocean | 0.00494 | - | - |
| Branch et al. [2] | Antarctic Ocean | - | - | 0.17–0.52 |
| Best et al. [46] | Madagascar South | 0.00055 | 1.24 | 3.62 |
| | Madagascar North | 0.00036 | 1.00 | 4.75 |
| Current study | Sri Lanka (All waters) (NIO) | 0.00791 | 2.69 | 27.2 |

The survey conducted in 1992 (April to July) in two ecosystems, the Western Tropical Indian Ocean (WTIO) and Eastern Pacific Ocean (EPO), recorded three blue whale sightings off the west coast of Sri Lanka [45]. The encounter rate and mean group size of those studies are much lower than the values recorded around Sri Lanka during the present study. Meanwhile, Priyadarshana et al. [6] estimated that the blue whale group encounter rate off the southern coast of Sri Lanka was 59 sightings/1000 km, which is one of the highest global records. The maximum survey effort of that study [6] was allocated from February to April, and additional individual days in each month of July, September and October. Studies on blue whale abundance in the Indian Ocean are scarce; however, in 1996–1997, one survey was conducted in the western Indian Ocean in the Madagascar Plateau [46]. Blue whale abundance in the north Pacific Ocean, off the west coast of the US and Mexico, was studied from 1991 to 1997 in four sub-areas: California inshore, California offshore, Baja and Oregon [35]. California inshore recorded a maximum density of 0.00494 whales/km$^2$, which is much lower than the estimated value of 0.00791 whales/km$^2$ in Sri Lanka.

## 5. Conclusions

Estimated abundance and density during the present study provide supporting evidence that the blue whale population in Sri Lanka is relatively abundant compared to the global status. Moreover, the concentration of a major part of the population in a heavy trafficking shipping area off of the southern and southwestern coastal regions of Sri Lanka during the SW monsoon, in addition to that previously documented during the NE monsoon [6], will increase risk of ship strikes and impacts from underwater noise. Therefore, for the effective conservation of this species and to reduce the risk of ship strikes, habitat

protection measures need to be considered; where possible, measures should be developed to minimize shipping traffic in the areas of whale concentration. Information sharing with ships regarding temporal and spatial whale aggregations, speed reduction and entry restrictions for whale habitats to reduce disturbance are highly recommended.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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