The need for taxonomic investigations on Northern Indian Ocean blue whales (*Balaenoptera musculus*): implications of year-round occurrence off Sri Lanka and India

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ABSTRACT

The blue whale (*Balaenoptera musculus*) is one of the most common cetaceans in the waters around Sri Lanka and in a worldwide context one of the highest low-latitude sighting rates for this species has been recorded in these waters. As genetic analyses, acoustic studies and even long-term sighting surveys for blue whales in these waters are limited, the taxonomic status and population affinities of these animals are not definitively known at present. Sighting records of this species were examined from the waters around Sri Lanka and stranding records from the coasts of both Sri Lanka and India in terms of seasonality of occurrence and it was found that the species is clearly present in these waters throughout the year. This, together with secondary data on certain morphological characteristics and behavioural anomalies, indicates that these waters are ecologically important to blue whales in the Northern Indian Ocean and questions are raised regarding the subspecific identity and population affinities of the animals in the region. It is not clear if they belong to either of the two subspecies currently recognised for the Southern Ocean and Indian Ocean region: their apparently non-migratory nature is akin to the pygmy blue whale *B.m. brevicauda*, while some morphological and behavioural characteristics are indicative of Antarctic blue whales of the subspecies *B.m. intermedia*. This raises the possibility of an entirely different or intermediate subspecies and the need to re-examine *B.m. indica* as a third subspecies in the Northern Indian Ocean. As clarifying their taxonomic status is important in the context of conservation and management, multi-disciplinary studies are urgently needed.

KEYWORDS: BLUE WHALE; NORTHERN INDIAN OCEAN; TAXONOMY; SUBSPECIES; NORTHERN HEMISPHERE

INTRODUCTION

The blue whale (*Balaenoptera musculus*) is the most common large mysticete in the waters around Sri Lanka (5°55'- 9°50'N; 79°42'- 81°53'E), in the Northern Indian Ocean (Ilangakoon, 2002; 2006b; Leatherwood and Reeves, 1989). Sighting rates for this species are high in these waters in comparison to other low-latitude regions of the world (Branch *et al.*, 2007). These animals are unique in that their northward movement is limited by a land barrier, namely the landmass of Asia. Primary productivity in the waters around Sri Lanka and India, as in other parts of the Northern India Ocean, is driven mainly by monsoon-related upwelling (Vinayachandran *et al.*, 2003; Vinayachandran and Mathew, 2003). While the ecology of the blue whale in this region is not yet clearly understood, it has been suggested that there is a resident population (Ballance and Pitman, 1998; Gordon *et al.*, 1986; Ilangakoon, 2002; 2006b; Leatherwood and Reeves, 1989) with a geographical distribution that does not overlap with those of Southern Indian Ocean populations (Branch *et al.*, 2007; Mikhalev, 2000). The breeding cycle of the Northern Indian Ocean blue whale is also out of phase with those in the Southern Indian Ocean (Mikhalev, 2000), indicating that there is no interbreeding with other populations.

Although blue whales are the largest mammals on the planet and were extensively hunted until the middle of the 20th century, little is known about their distribution and migration patterns in the Northern Indian Ocean (Branch *et al.*, 2007). The two currently recognised subspecies of blue whale in the Southern Ocean and Indian Ocean region are the Antarctic blue whale (*Balaenoptera musculus intermedia*) and the pygmy blue whale (*B.m.brevicauda*). The Antarctic blue whale is believed to remain south of 55°S in the austral summer, while pygmy blue whales generally remain north of 54°S (Ichihara, 1966; Kato *et al.*, 1995). These two subspecies are not easy to distinguish in the field though Antarctic blue whales attain a greater total length (>30m as against 24.1m) and have a proportionately longer tail region compared with pygmy blue whales (Ichihara, 1966; Mackintosh and Wheeler, 1929). Other morphological characteristics distinguishing the two subspecies include a 'torpedo' body shape in the Antarctic blue whale as opposed to a 'tadpole' shape with a proportionately larger head in the pygmy blue whale and differences in the relative position of the central groove of the blowhole, which usually ends with the anterior margin of the nostrils in the Antarctic blue whale but extends beyond the nostrils in the pygmy blue whale (Kato *et al.*, 2001). *Balaenoptera indica* was suggested in the middle of the 19th century (Blyth, 1859) as a separate species occurring in the Northern India Ocean but is not widely recognised because its distinguishing features are unclear (Rice, 1998). It is currently not definitively known if the blue whales in the Northern Indian Ocean, including those around Sri Lanka and India (Fig. 1), belong to either of the two accepted subspecies.

Through an examination of sighting records from around Sri Lanka over the past three decades, combined with historical and recent stranding data from India and Sri Lanka, the ecological importance of these waters to blue whales was evaluated and questions regarding their affinity to the

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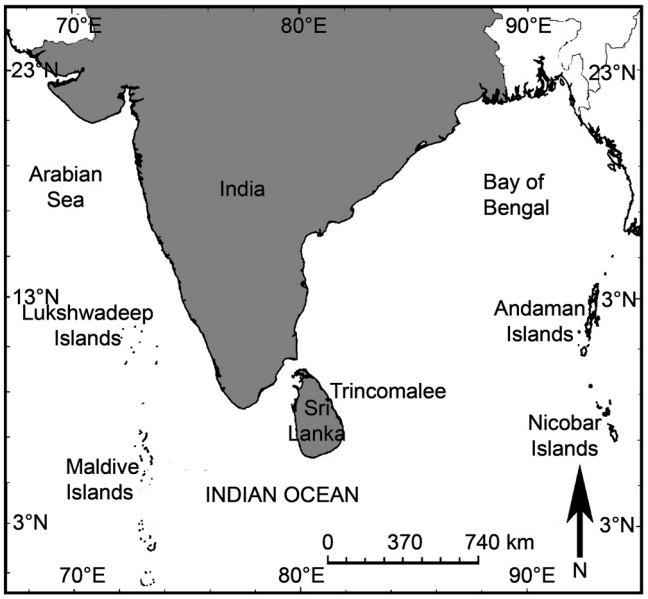

Fig. 1. Study location.

currently accepted subspecies were addressed. Limited morphological and behavioural observations were used as supporting secondary data and the possibility that the species described earlier as *B. indica* is actually a third distinct Northern Indian Ocean, subspecies of blue whale, that would merit the name *Balaenoptera musculus indica* by the rules of nomenclature was considered. Attention is drawn to research limitations in this region and the need for taxonomic evaluation of blue whales in the Northern Indian Ocean in order to close the current gaps in knowledge, which could have long-term conservation and management implications.

METHODS

All published records of blue whale strandings that occurred on the coasts of Sri Lanka and India between 1894 and 2004 were initially listed separately for the two countries by extracting them from compilations of cetacean stranding records for the two countries by Ilangakoon (2002; 2006b) and Sathasivam (2004). Subsequently these records were collated with data from more recent publications (Afsal and Rajagopalan, 2007; Baby, 1999; Jayasankar *et al.*, 2006; Krishnan *et al.*, 2004) and one comprehensive list was developed for closer examination. Strandings of this species occurring after 2004 but not yet reported in the literature were included in this analysis if the specimens had been examined personally by one of the present authors and authenticated as being blue whales.

Published blue whale sightings data are currently available in any quantifiable manner only for Sri Lanka and not for Indian waters. Therefore, all sighting records from published sources for which a clear date of sighting and area of sighting were available (Branch *et al.*, 2007; Ilangakoon, 2002; 2006a; Leatherwood and Reeves, 1989) were compiled separately from the strandings data. Unpublished but reliable sightings from cetacean survey reports (Ocean Alliance, 2003) and unpublished data from project reports of recent surveys undertaken by the first author (Ilangakoon, 2009; Ilangakoon and Perera, 2008; 2009) in Sri Lankan waters were included. All Sri Lankan sources are listed in Table 1. As these data are from several different surveys, the methodology is not standardised either in relation to observer effort or in terms of temporal and spatial coverage. Some of the published data used are from opportunistic observations made during oceanographic surveys where a single marine mammal observer was on board. While none of the surveys were undertaken purely for the purpose of observing blue whales, the majority were cetacean surveys.

Morphological data and behavioural observations on blue whales around Sri Lanka from published material (Alling *et al.*, 1991) as well as from recently concluded and yet unpublished surveys undertaken by the first author off southern Sri Lanka in the 2008/2009 field season

Table 1

Blue whale sighting records from Sri Lanka.

Month/year	Area	No. of animals	Source
March 1985	Northeast	2	Leatherwood and Reeves (1989)
March 1985	Northeast	1	Leatherwood and Reeves (1989)
March 1985	Northeast	1	Leatherwood and Reeves (1989)
May 1985	Southwest	1	Leatherwood and Reeves (1989)
May 1985	Southwest	1	Leatherwood and Reeves (1989)
December 1985	Southwest	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
December 1985	South	1	Leatherwood and Reeves (1989)
February 1987	Northeast	1	Branch *et al.* (2007)
February 1987	Northeast	1	Branch *et al.* (2007)
February 1987	Northeast	3	Branch *et al.* (2007)
February 1987	Northeast	1	Branch *et al.* (2007)
February 1987	Northeast	1	Branch *et al.* (2007)
March 1987	Northeast	1	Branch *et al.* (2007)
March 1987	Northeast	1	Branch *et al.* (2007)
March 1987	Northeast	1	Branch *et al.* (2007)
March 1987	Northeast	1	Branch *et al.* (2007)
March 1987	Northeast	1	Branch *et al.* (2007)
May 1994	West	1	Ilangakoon (2002)
July 1994	West	2	Ilangakoon (2002)
August 1994	West	1	Ilangakoon (2002)
August 1994	West	1	Ilangakoon (2002)
April 2003	Southeast	2	Ocean Alliance (2003)
April 2003	West	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	1	Ocean Alliance (2003)
April 2003	Southeast	2	Ocean Alliance (2003)
June 2003	West	1	Ocean Alliance (2003)
October 2003	West	7	Branch *et al.* (2007)
August 2004	Northwest	2	Ilangakoon (2006a)
September 2008	South	4	C. Jayatilleke, pers.comm/pics
November 2008	South	1	Ilangakoon and Perera (2009)
November 2008	South	9	Ilangakoon (2009)
November 2008	South	2	Ilangakoon (2009)
November 2008	South	1	Ilangakoon (2009)
December 2008	South	1	Ilangakoon and Perera (2009)
January 2009	South	1	Ilangakoon (2009)
February 2009	South	4	Ilangakoon and Perera (2009)
February 2009	South	1	Ilangakoon (2009)
February 2009	South	2	Ilangakoon (2009)
February 2009	South	7	Ilangakoon (2009)
February 2009	South	5	Ilangakoon (2009)
March 2009	South	1	Ilangakoon and Perera (2009)
April 2009	South	2	Ilangakoon and Perera (2009)
April 2009	South	1	Ilangakoon and Perera (2009)
April 2009	South	3	Ilangakoon and Perera (2009)
April 2009	South	1	Ilangakoon and Perera (2009)

(Ilangakoon, 2009; Ilangakoon and Perera, 2009) were also examined as secondary or supplementary data. Given the general dearth of survey effort in the area, these recent and yet unpublished observations, though not quantifiable, were used to add important new perspectives to the analysis.

Strandings were examined in terms of stranding events and not in terms of the number of animals. Sightings were also primarily examined in terms of the number of separate sightings, but data on the number of animals in each sighting as well as observed behaviour were also investigated. Stranding data from India and Sri Lanka were examined by month of stranding. Sightings data from Sri Lanka were similarly examined in terms of time of year to determine when blue whales are present.

RESULTS

Seasonality of sightings and strandings are reported here through examination of primary data. Additionally, morphological characteristics and behavioural observations are considered as secondary data that support the primary data.

Seasonality of sightings and strandings

Data are available for 40 blue whale strandings on the coasts of Sri Lanka (17) and India (23) between 1894 and the present. Two older records from Sri Lanka were excluded as they did not include the stranding month. Sightings are detailed in Table 1 and summarised in Fig. 4. Accordingly, 38 records from the two countries were examined by month of stranding. The most significant factor to emerge is that blue whale strandings have occurred along the coasts of the two countries in all months of the year (Fig. 2). Overall numbers for the two countries peaked in May, but in general strandings are randomly distributed throughout the year. There are months for which strandings have been reported only from one country and not the other, but as the two countries are located very close to each other, the distinction was not considered to be significant. Most strandings have been of single animals, with a single record of two animals (a female and a calf) stranding at the same location on the west coast of Sri Lanka in 1984 (Ilangakoon, 2002).

A total of 51 sightings was available from Sri Lanka (Table 1). There are sightings in every month of the year (Fig. 3), with a clear peak from February–April and a smaller peak in November–December. Smaller numbers of sightings were recorded between May and October.

The majority (67%) of sightings were of single animals, while 16% were of two animals together (Fig. 4). Smaller percentages of sightings were recorded for groups consisting of 3, 4, 5, 7 and 9 animals in close proximity to each other and moving in a coordinated fashion, indicating that they were part of a single unit. Most cow-calf pairs observed were among those groups.

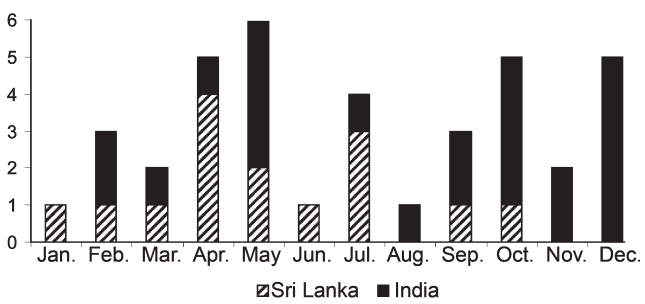

Fig. 2. Blue whale strandings in Sri Lanka and India from 1894 to the present.

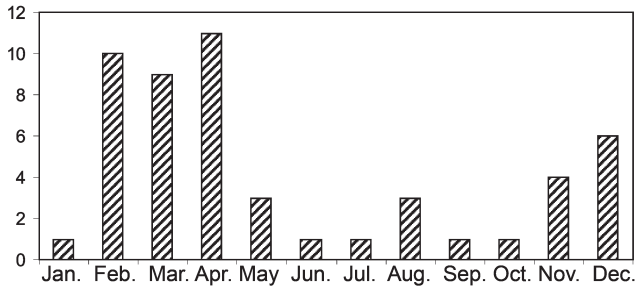

Fig. 3. Blue whale sighting events from Sri Lanka.

Morphology

Kato *et al.* (2001) described three blowhole types that can be used to distinguish pygmy blue whales from Antarctic blue whales in the field: Type A, where the anterior tip of the central groove extends beyond the anterior tip of the nostril; Type B, where the anterior tip of the central groove ends at the anterior tip of the nostril and Type C, where the anterior tip of the central groove is inside the anterior tip of the nostril. During the 2008–09 field season the majority of sightings were of Type A blowholes, but at least two blue whales with a Type B blowhole were observed off southern Sri Lanka and one with a Type C blowhole was observed (Ilangakoon, unpublished data).

Several of the stranded animals from both Sri Lanka and India were close to the maximum recorded length of pygmy blue whales, 24m (Table 2), while two animals from India exceeded that length, at 26m and 28.2m respectively. The largest animal (28.2m) stranded during the austral summer (Table 2).

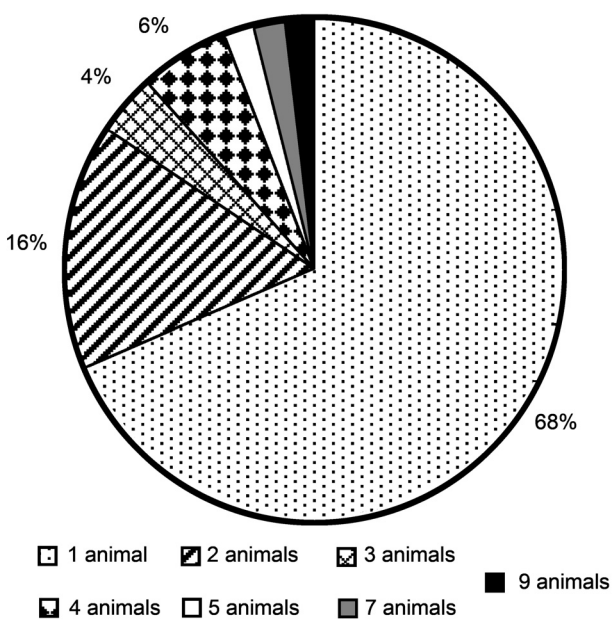

Fig. 4. Group sizes of blue whales sighted off Sri Lanka.

Table 2
Strandings of blue whales exceeding 22m in total length.

Month/year	Length (m)	Sex	Location	Source
Nov. 1927	28.2	N/A	Cochin, India.	Moses (1947)
Mar. 1939	23.7	N/A	Kathiawar, India	Moses (1947)
May 1951	22.2	N/A	Bombay, India	Chari (1951)
Dec. 1960	23.4	N/A	Gujarat, India	James and Soundararajan (1979)
May 1993	26.0	N/A	Cochin, India	James *et al*. (1993)
Jul. 1999	23.8	F	Weligama, Sri Lanka	Ilangakoon (2006)
Jun. 2009	23.3	M	Chilaw, Sri Lanka	Ilangakoon (unpublished data)

Behavioural observations

Alling *et al.* (1991) reported feeding activity in northeastern waters of Sri Lanka. Re-sighting of individually identified animals off Trincomalee in consecutive years was reported by both Leatherwood (1985) and Alling *et al.* (1991). Ilangakoon (2002) reported frequent sightings of blue whales in continental shelf waters during the south-west monsoon off the west coast of Sri Lanka in 1994. Blue whales were also observed feeding along the edge of the continental shelf between November and April during recent cetacean surveys off the south coast in the 2008–09 field season (Ilangakoon, 2009; Ilangakoon and Perera, 2009).

Feeding behavioural patterns observed in southern Sri Lanka include frequent fluke-up dives lasting 7–18 minutes, with whales resurfacing repeatedly in the same area, and subsurface skimming with occasional surface lunging. Alling *et al.* (1991) reported whales diving and resurfacing in pairs; the same synchronised diving behaviour was observed off the south coast in the 2008–09 field season (Ilangakoon, 2009; Ilangakoon and Perera, 2009), in three separate sightings. These pairs consisted of animals of similar size, as opposed to cow-calf pairs, as also observed by Alling *et al.* (1991) in the northeast.

In southern Sri Lanka the most frequently observed surfacing pattern for undisturbed adult blue whales was the appearance of the head followed by rounding of the back, showing the dorsal fin and dorsal keel with the tail stock arched and frequent lifting of the flukes 'fluking up' before submerging. The diving behaviour of mother-calf pairs off the south coast was similar in all sightings, with calves diving in synchrony with the accompanying adult, but while the adults usually raised their flukes at the onset of a dive, none of the calves raised their flukes above the surface but only displayed an arched tail stock. The dives of these cow-calf pairs were generally short in duration, lasting from 3 to 9 minutes.

Alling *et al.* (1991) noted that the blue whales seen in Sri Lanka often lifted their flukes above the water before they dived, allowing fluke photographs to be taken for identification purposes. In observations during the 2008–09 field season adult blue whales off the south coast raised their flukes out of the water on approximately 70% of dives. Only when diving hurriedly due to disturbances caused by whale watching boats did they dive without fluking up.

Acoustic recordings made in the Indian Ocean have enabled the identification of three distinct blue whale call types (Alling *et al.*, 1991; Ljungblad *et al.*, 1998; McCauley *et al.*, 2001) attributed to pygmy blue whales because they have only been recorded north of 60°S. One of these call types was first recorded in 1984 off northeast Sri Lanka (Alling *et al.*, 1991) and subsequently the same type of call was recorded near Diego Garcia, south of the equator (McDonald *et al.*, 2006; Stafford *et al.*, 2005). However, these calls are distinct from pygmy blue whale calls recorded off Madagascar and Australia (Branch *et al.*, 2007).

Cow-calf pairs were observed off the northeastern coast of Sri Lanka in both 1983 and 1984 in February–March (Alling *et al.*, 1991). Likewise, in the 2008–09 field season cow-calf pairs were encountered off the south coast on two occasions, in November and February. A sighting on 11 November 2008 was of particular interest as two cow-calf pairs were sighted in close proximity to each other among a feeding aggregation of nine individuals (Ilangakoon, 2009). Additionally, there is a single record of a female and calf stranding together on the west coast of Sri Lanka in February 1984 (Ilangakoon, 2002).

A blue whale was observed breaching repeatedly off southern Sri Lanka and photographed from a distance by whalewatchers on 10 March 2009 (Fig. 5).

DISCUSSION

This analysis demonstrates that blue whales are present in the Northern Indian Ocean waters around Sri Lanka and India during all months of the year. While strandings in both countries are distributed throughout the year, the peaks in sightings in certain months may not reflect the actual abundance of blue whales in different months of the year, but rather the sea conditions suitable for surveys to be carried out and opportunistic observations to be made. The small numbers of sightings from May to October are certainly the result of the south-west monsoon, which prevails during this period and makes cetacean surveys off the west and south coasts of Sri Lanka nearly impossible from May to August and difficult due to unpredictable seas in September–October. Therefore, although the peaks and troughs in sightings may not be indicative of the actual abundance of animals present, they show that blue whales were present in the waters around Sri Lanka during periods when survey effort was minimal.

The general view of blue whale migration is that Antarctic blue whales remain in waters south of 55°S in the austral summer and venture northwards into temperate waters, e.g. around southern Africa, in winter, while pygmy blue whales do not migrate to Antarctic waters but generally remain north of 54°S at all times (Ichihara, 1966; Kato *et al.*, 1995). Accordingly, it has been assumed that blue whales in the Northern Indian Ocean are all pygmy blue whales (Alling *et al.*, 1991; Mikhalev, 2000; Yochem and Leatherwood, 1985) although their taxonomic status is as yet uncertain due to the extremely limited number and nature of taxonomic studies there.

Some authors have suggested that blue whales in the Northern Indian Ocean undertake a roughly east-west migration, taking advantage of monsoon upwellings around Somalia and Arabia, from May to October, dispersing eastwards and southwards towards the Maldives and Sri

Fig. 5. Breaching blue whale off southern Sri Lanka.

Lanka from November to April (Anderson, 2005; Anderson *et al.*, 1999). Previous surveys limited to the water off northeast Sri Lanka found blue whales to be rare around Sri Lanka between May and October (Alling *et al.*, 1991; Leatherwood *et al.*, 1984). Based on these reports and the seasonal presence of blue whales in the waters around the Maldives, it was suggested that the animals passing the Maldives from November to April were the same as those that appeared off the northeast coast of Sri Lanka from December to April (Anderson, 2005). Several authors have suspected that at least a part of the blue whale population in the tropical Northern Indian Ocean may remain year-round in high-productivity areas including the waters off Sri Lanka (Branch *et al.*, 2007; Ilangakoon, 2002; 2006b). Subsequent studies off the Sri Lankan west and south coasts (Branch *et al.*, 2007; Ilangakoon, 2006a; 2009; Ilangakoon and Perera, 2009; Ocean Alliance, 2003) have confirmed that blue whales are present in Sri Lankan waters at all times of the year. The east-west movement theory does not fit neatly with these findings or with the present analysis, which takes into account both live sightings and strandings. It fails to explain the high sighting rates or how and why blue whales are present around Sri Lanka and India throughout the year. Branch *et al.* (2007) suggested that the classic theory of migration patterns for blue whales may be in need of revision and we agree with this suggestion insofar as it applies to the Northern Indian Ocean population.

Based on the currently examined data an alternative hypothesis is that the blue whales in this part of the Northern Indian Ocean undertake extremely localised movements within a small but highly productive, monsoon-driven feeding area. While blue whale ecology in the Northern Indian Ocean is poorly understood, a few feeding areas have been identified in the Indian Ocean, including off Sri Lanka in the past two decades (Alling *et al.*, 1991; Gill, 2002; Ilangakoon, 2009). Sri Lanka has a relatively narrow continental shelf (Wijeyananda, 1997) and, being located just south of the Indian Subcontinent, with no landmass to its south, is affected by both the south-west and north-east monsoons (Shankar *et al.*, 2002; Vinayachandran *et al.*, 2003). The north-east monsoon affects the northeast coast of Sri Lanka and adjacent waters from November to March, the time when blue whales are abundant in the waters around Trincomalee, as reported by Alling *et al.* (1991), who suggested that these waters are an important feeding ground. The outfall of Sri Lanka's largest river, the Mahaweli, is located in Trincomalee and deposits the largest volume of nutrient-rich waters at this time of the year, enhancing productivity in the area. Re-sightings of individually identified animals in consecutive years also indicate site fidelity to these productive feeding grounds. Vinayachandran and Yamagata (1998) suggested that a thermal dome forms east of Sri Lanka from May to July, modifying the upper ocean thermal structure and maintaining cooler water temperatures within it. As a result, cooler, nutrient-rich water is brought to the surface by open-ocean upwelling within this dome. Though no blue whale sightings have been reported from the northeastern waters during this period (Alling *et al.*, 1991), two strandings have occurred in May (Ilangakoon, 2006b) and it is possible that the whales move further offshore at this time in order to take advantage of the open-ocean upwellings created by the thermal dome. In doing so, they may have moved out of the area covered by the surveys in 1983 and 1984. Concurrently, the south-west monsoon creates upwelling and nutrient enrichment through river outfalls off the south and west coasts from May to September and localised upwelling occurs between the southern tip of India and Sri Lanka (Rao *et al.*, 2006). Both sightings and strandings have been recorded from the west, northwest, south and southeast coasts during the period of the south-west monsoon (Ilangakoon, 2002; 2006a; 2006b; 2009; Ilangakoon and Perera, 2009; Ocean Alliance, 2003). However, sightings and feeding off the south coast are not limited to this monsoon period but have also been recorded during the north-east monsoon (Ilangakoon, 2009; Ilangakoon and Perera, 2009), indicating that feeding opportunities are not limited to monsoon-related upwelling.

The implications are that blue whales around Sri Lanka and India exploit seasonal upwelling-related food sources and at least a part of the population is able to find enough sustenance there throughout the year. Ballance and Pitman (1998) have also suggested that blue whales in the Western Indian Ocean and Eastern Tropical Pacific track localised areas of high productivity to take advantage of feeding opportunities in low latitudes. Based on the data presented here it is suggested that in the Northern Indian Ocean similar feeding opportunities allow blue whales to remain in low-latitude waters around Sri Lanka throughout the year. Based on work in other low-latitude areas, it has also been suggested that certain populations of blue whales, along with other baleen whales, remain in such waters throughout the year (Bannister, 2002; Hucke-Gaete *et al.*, 2004; Mikhalev,

1997). Remaining throughout the year in areas with adequate food is also reported for Antarctic blue whales, as catch data and acoustic recordings have shown that some blue whales over-winter in Antarctic waters instead of migrating north (Harmer, 1931; Hinton, 1915; Risting, 1928; Sirovic *et al.*, 2004).

Given the above, questions arise about the taxonomic status and stock affinities of these animals. However, owing to the lack of historical data for these waters, it is not known if this year-round presence has been a constant phenomenon over the ages. If the animals have been non-migratory over long periods of time, it is even possible that they are of an entirely different subspecies from the two currently recognised for the Southern Ocean and Indian Oceans. Mikhalev (2000) concluded that the Northern Indian Ocean blue whale population is isolated and suggested further studies to determine the extent of this isolation, which is in agreement with this study. Further, a different species, *B. indica* (Blyth, 1859), described in the mid 19th century from the Northern Indian Ocean, though currently not accepted as a species, warrants re-evaluation as a possible subspecies, *B. m. indica*.

Uncertainty regarding the taxonomic status of these Northern Indian Ocean blue whales is compounded by the limited morphological observations on blue whales available from Sri Lanka and India. According to Kato *et al.* (2001), the Type B blowhole is most common in Antarctic blue whales, while Type A is peculiar to pygmy blue whales and Type C is occasionally seen in pygmy blue whales. Contrary to what may be expected, two animals sighted off southern Sri Lanka in 2008–09 had Type B blowholes. Likewise, it is accepted that the pygmy blue whale does not exceed 24.1m in total length, while Antarctic blue whales can attain lengths of over 30m (Branch *et al.*, 2007; Rice, 1998; Sears and Perrin, 2009). Some of the stranded animals in Sri Lanka and India were very large, with a stranding of the largest animals during early austral summer, when, according to the classic migration theory, Antarctic blue whales should be feeding in Antarctic waters. However, it has already been noted that there is uncertainty regarding the accuracy of length measurements in the earlier strandings as it is not known how the measurements were made.

Behavioural observations add weight to the possibility that the blue whales around Sri Lanka are different from blue whales found elsewhere. Surfacing patterns of undisturbed adult blue whales observed off southern Sri Lanka are different from surfacing patterns typical of pygmy blue whales, wherein the dorsal fin and keel are not always seen in the surfacing sequence (Kato *et al.*, 2001). In Sri Lanka the dorsal fin and arched tail stock were always seen and often the flukes were also seen before submergence. This is a surfacing pattern more commonly seen in the Antarctic blue whale. The frequent fluking behaviour reported from the northwest and south of Sri Lanka during different studies is not typical of blue whales described from elsewhere in the world. Similar percentages (73%) have been recorded only from the Maldives (Anderson, 2005), which is also in the Northern Indian Ocean and in close proximity to the present study area. Blue whales are generally reported to fluke up on only 18% of dives (Sears and Perrin, 2009), but in Sri Lanka this behaviour is observed on a much higher percentage (70%) of dives. Fluking up is a behavioural characteristic that may simply represent prevailing motivation, such as feeding, and hence these observations are invoked here only as secondary data that indicate an unusual form of behaviour.

Acoustic data suggest some sort of north-south movement of animals between Sri Lanka and Diego Garcia, south of the equator and it is therefore possible that only a part of the blue whale population in the Northern Indian Ocean around Sri Lanka and India remains there throughout the year, while some animals may undertake longer migrations. This also leads to questions regarding blue whale breeding areas in the Indian Ocean because little is known about where either of the presently accepted subspecies calve or mate (Mackintosh, 1966; Stafford *et al.*, 2004). Though it has been assumed that Antarctic blue whales migrate to temperate mating and calving areas in the winter (Branch *et al.*, 2007), the actual areas where they breed in the Indian Ocean have yet to be identified (Sears and Perrin, 2009). Likewise, little is known about the breeding areas of the pygmy blue whale in the Indian Ocean. While cow-calf pairs were observed between November and February off southern Sri Lanka, similar sightings have been recorded south of Madagascar in December (Best *et al.*, 2003). Mikhalev (2000) recorded late prenatal stage foetuses and those in the early stages of development in catches from the Arabian Sea in November–December and concluded that Northern Indian Ocean blue whales have a breeding cycle six months out of phase with populations in the south. All the sightings of cow-calf pairs off Sri Lanka in different years, despite limited survey effort and the single stranding of a cow-calf pair, raise questions as to whether the waters around Sri Lanka could be a blue whale breeding area in addition to being a feeding area. Within the past decade, a blue whale feeding and nursing ground was discovered near Chile in the Pacific Ocean (Hucke-Gaete *et al.*, 2004) and the waters near Sri Lanka may be similarly important in the Indian Ocean.

It has been noted that vigorous surface activity such as raising the body high out of the water, porpoising forward and even occasionally breaching is possibly a part of blue whale mating behaviour (Sears and Perrin, 2009) and the repeated breaching behaviour of a blue whale off southern Sri Lanka in March 2009 is of interest in this respect. It has also been reported previously that lactating pygmy blue whale females with large calves are observed in the same regions where mating occurred (Mikhalev, 2000), strengthening the possibility that the waters around Sri Lanka are of importance to Northern Indian Ocean blue whales for breeding purposes. Breeding around Sri Lanka or somewhere near it could also explain blue whales' year-round presence there. It is possible that calving females remain throughout the year while other animals of the same population migrate southwards seasonally towards Diego Garcia, but not far enough to mingle with other reproductive groups.

All the foregoing indicates that the waters around Sri Lanka and India are ecologically important to blue whales and leads to the question as to whether these blue whales in the Northern Indian Ocean belong to either of the presently recognised subspecies or are of an entirely different subspecies. It is indeed curious that they display movement patterns similar to those of pygmy blue whales, certain morphological

characteristics similar to those of Antarctic blue whales and some anomalous behavioural characteristics. Another possibility, however, is that animals from two different subspecies use these waters without intermingling, as has been reported from areas in the Eastern Tropical Pacific near Chile and Peru (Berzin, 1978; Donovan, 1984; Ichihara, 1981), where blue whales are also found year-round (Palacios, 1999; Reilly and Thayer, 1990), as in the vicinity of Sri Lanka.

The present data clearly raise more questions than provide answers in relation to the taxonomic affinities of the Northern Indian Ocean blue whales. Taxonomic investigations on the blue whales around Sri Lanka and India are urgently needed. This is particularly important as populations of both the Antarctic blue whale and, to a lesser extent, the pygmy blue whale are considerably depleted due to whaling in the past (Branch *et al.*, 2004) and are recovering only slowly. The IUCN Red List of threatened species (IUCN, 1996) lists the Antarctic blue whale as 'Endangered', while the pygmy blue whale is currently listed as 'Data Deficient' due to its uncertain status. Accordingly genetic studies on Northern Indian Ocean animals should be considered a matter of priority in order to compare their genetic affinities with animals from other regions and to resolve their taxonomic status. Photo-identification could also add valuable information in relation to movement patterns and habitat use in the long-term. Likewise, little is known about what blue whales actually feed on in this area. Examination of faeces and plankton hauls in the vicinity of feeding animals should provide valuable information on feeding habits. Multi-disciplinary studies are therefore needed. Such knowledge could have implications for the conservation, long-term management and maintenance of genetic diversity of blue whales in the Northern Indian Ocean.

ACKNOWLEDGEMENTS

We thank two anonymous reviewers for their constructive comments and suggestions. We acknowledge financial support from the Whale and Dolphin Conservation Society (WDCS) and Ocean Park Conservation Foundation, Hong Kong (OPCF) for surveys off south and southwest Sri Lanka. We thank Lester Perera, Ramani Jayewardene, Chinthaka de Silva and Uditha Hettige for assisting with data collection, Ajith Perera for photographs of the breaching blue whale and Chitral Jayatillaka for data on a sighting. We also thank Edwin Joseph of the Central Marine Fisheries Research Institute, Cochin, for all help offered in compiling data and K.S. Natarajan of the Marine Mammal Conservation Network of India for encouragement and support.

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Date received: March 2010.
Date accepted: October 2010.