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Lisa T. Ballance
*NOAA, NMFS, Southwest Fisheries Science Center*, Lisa.Ballance@noaa.gov

R. Charles Anderson
*Marine Research Centre, Ministry of Fisheries Agriculture and Marine Resources, H. Whitewaves, Male', Republic of Maldives*

Robert L. Pitman
*NOAA, NMFS, Southwest Fisheries Science Center*

Kathleen Stafford
*Alaska Fisheries Science Center/National Marine Mammal Laboratory*

Abdullah Shaan
*Marine Research Centre, Ministry of Fisheries Agriculture and Marine Resources, H. Whitewaves, Male', Republic of Maldives*

*See next page for additional authors*

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LISA T. BALLANCE[*], R. CHARLES ANDERSON[+], ROBERT L. PITMAN[*], KATHLEEN STAFFORD[++], ABDULLAH SHAAN[+], ZAHA WAHEED[+], ROBERT L. BROWNELL, JR.[*]

*Contact e-mail: Lisa.Ballance@noaa.gov*

ABSTRACT

In April 1998, as part of a project to collect biopsy samples of putative pygmy blue whales (*Balaenoptera musculus brevicauda*) in the waters around the Republic of the Maldives, Indian Ocean, incidental sightings of cetaceans encountered were recorded. Using modified line-transect methods and handheld binoculars, a total of 267 sightings of 16 species of whales and dolphins were recorded during 20 at-sea days in the northeastern part of the atoll. Significant results include the following: (1) cetaceans were abundant and species diversity was high, including nearly every pantropical species of pelagic cetacean; (2) the spinner dolphin (*Stenella longirostris*) was by far the most common species encountered (56 sightings) and also had the largest mean school size ( = 50.3 individuals); (3) blue whales were rare; only four individuals were sighted; (4) a large concentration of Bryde's whales (28 sightings in two days) was apparently feeding in nearshore waters; (5) this paper reports the first records for the Maldives of Cuvier's beaked whale *(Ziphius cavirostris)*, Blainville's beaked whale *(Mesoplodon densirostris)* and the dwarf sperm whale (*Kogia sima*): the latter was particularly common (17 sightings); (6) the spotted dolphin *(Stenella attenuata)* was rare and almost always associated with yellowfin tuna (*Thunnus albacares*), spinner dolphin, or seabirds, as has been reported in the eastern Pacific and western Indian oceans.

KEYWORDS: FEEDING GROUNDS; INDIAN OCEAN; SANCTUARIES; INCIDENTAL SIGHTINGS; SURVEY-VESSEL; TAXONOMY; BIOPSY SAMPLING; PHOTO-ID; BLUE WHALE; BRYDE'S WHALE; PANTROPICAL SPOTTED DOLPHIN; SPINNER DOLPHIN

## INTRODUCTION

The Republic of the Maldives in the central Indian Ocean consists of an archipelago of approximately 1,200 islands in a series of atolls which straddle the equator from 7°N to 1°S (Fig. 1). These islands are of interest to cetologists for several reasons. First, relatively little is known about the cetaceans of the region; there have been no systematic at-sea surveys for cetaceans in the area, and apart from occasional stranding reports (e.g. Anderson *et al.*, 1999), there is little to indicate which species are present and their relative abundance. This lack of information is significant, as the Maldives are located within the Indian Ocean Sanctuary, established in 1979 (IWC, 1980, p.27) to encourage conservation and research of cetaceans in the area (Anon., 1981).

Secondly, populations of large whales here are of special interest, as they are potentially recovering from commercial exploitation; this situation provides an opportunity to monitor this process. In particular, this area may be critical to the recovery of north Indian Ocean blue whales (*Balaenoptera musculus*), as there is evidence that a resident population occurs in the Sri Lanka/Maldives area (Alling *et al.*, 1991; Ballance and Pitman, 1998). Soviet whalers took 1,294 blue whales from the Arabian Sea during 1963-67 (Mikhalev, 1996) and presumably severely depleted the population because there have been relatively few sightings reported since then. Based on catch data, Mikhalev (1996) recognised four areas of concentration within the western tropical Indian Ocean but the only recent sightings come from the Sri Lanka/Maldives area (Alling *et al.*, 1991; Ballance and Pitman, 1998). The taxonomic status of this population is unclear. Both Alling *et al.* (1991) and Mikhalev (1996) suggested that these were pygmy blue whales (*Balaenoptera musculus brevicauda*). However, because north Indian Ocean blue whales are geographically isolated from known populations of *Balaenoptera musculus brevicauda* farther south, and because a blue whale stranded at Sondip in the Bay of Bengal, India, was described as a separate species (*Balaenoptera indica*; Blyth, 1859; see Rice, 1998 for discussion of type locality), the taxonomic status of the northwestern Indian Ocean blue whale populations remains unresolved (Brownell and Donahue, 1994; Rice, 1998).

Finally, there is substantial interest among Maldivians in understanding and protecting their natural resources, including cetaceans. There is no evidence that large whales were ever hunted here and the only directed take of dolphins (as bait in the fishery for tiger sharks, *Galeocerdo cuvier*) ceased in the early 1960s (Anderson *et al.*, 1999). Today, the capture of cetaceans is banned under Maldivian law (Anderson *et al.*, 1999). Thus, research here, in cooperation with local scientists and resource managers, will encourage maintenance of programmes focused on the biology and conservation of whales and dolphins.

With this in mind, the primary objective of the survey described here was to investigate the status of blue whales around the Maldives and to collect biopsy samples for molecular genetic analysis. A secondary objective was to record occurrence and relative abundance of other cetacean species in the area. Although relatively few blue whales were encountered, considerable information on the status of other cetacean species in the Maldives was collected.

## METHODS

The survey was conducted aboard an 18m motor vessel from 2-21 April 1998 (20 days). Effort was designed to maximise chances of encountering blue whales. Thus, tracklines covered primarily the northeastern part of the archipelago,

[*] *NOAA, NMFS, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037 USA.*
[+] *Marine Research Centre, Ministry of Fisheries Agriculture and Marine Resources, H. Whitewaves, Male', Republic of Maldives.*
[++] *Alaska Fisheries Science Center/National Marine Mammal Laboratory, 7600 Sand Point Way N.E., Seattle, WA 98115, USA.*

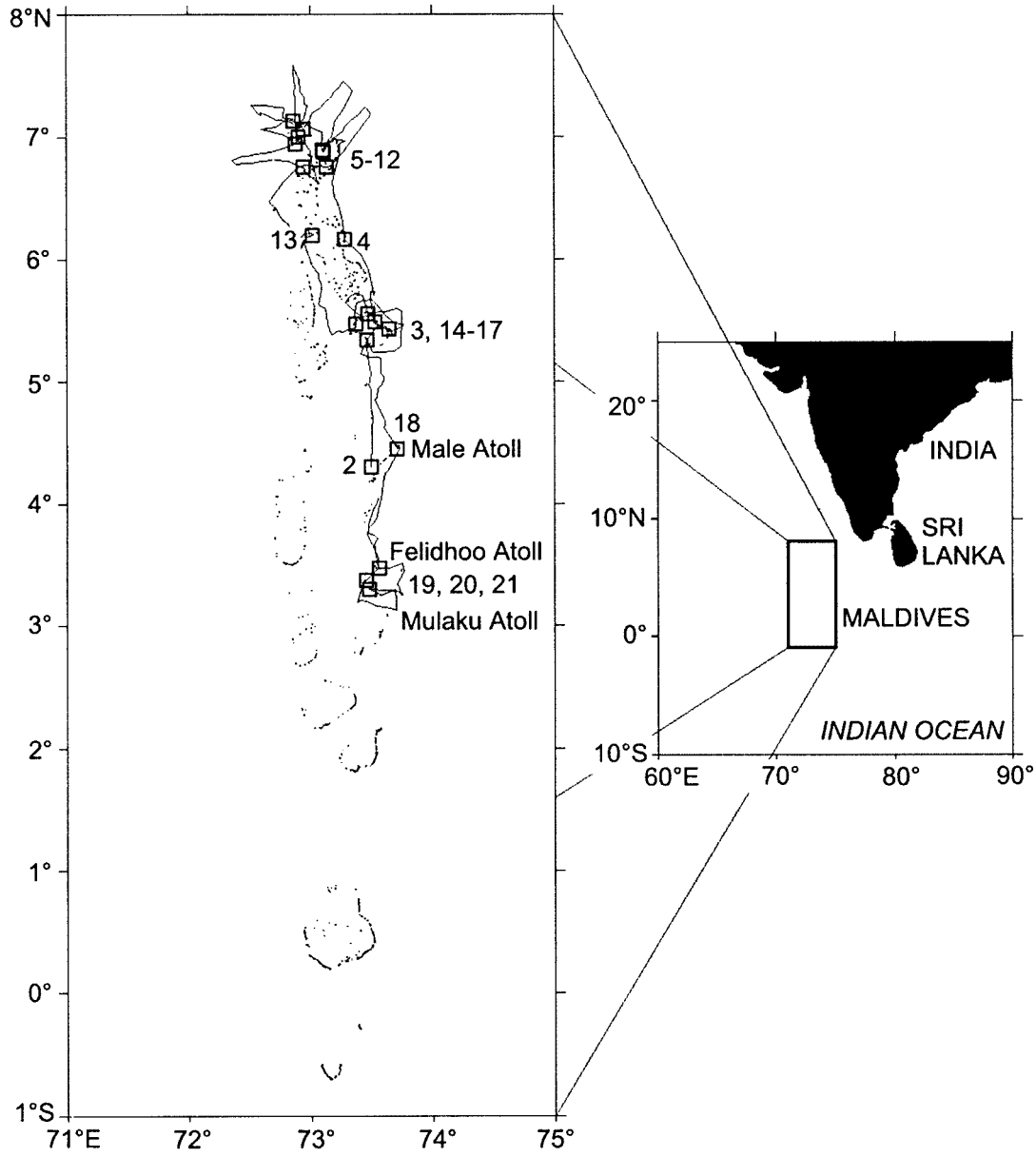


Fig. 1. Map of the Republic of the Maldives and survey effort. Islands can be seen as dots; they outline a series of north-south oriented atolls. Small squares along the trackline represent locations for start of effort on each day. Numbers correspond to dates in April of 1998 where survey effort was focused.

near where this species had been previously encountered (Ballance and Pitman, 1998) and effort was spent almost entirely in deep waters outside atolls (Fig. 1). With the exception of survey in the far north, effort occurred within 50km of the nearest island.

Data were collected using line transect methods (Buckland *et al.*, 1993), modified slightly as follows. Between two and six persons maintained visual watch during all daylight hours, weather permitting, from a platform approximately 4m above the water. Vessel speed was approximately 11km/h (six knots). Observers used handheld binoculars or unaided eye to scan for cetaceans. Every hour, or when conditions changed, vessel position (using a handheld GPS), Beaufort sea state and sighting conditions (excellent, good or fair) were recorded.

When a cetacean sighting was made, vessel position and the estimated distance (nautical miles) and angle to the sighting were recorded, then the vessel was turned and the school approached in order to obtain species identification, estimate school size and make notes on behaviour. For selected species, several types of additional data were collected. Skin biopsy samples were obtained using a crossbow with floating darts fired from the bow of the vessel or from a 3m inflatable launch. All biopsy samples are held at Southwest Fisheries Science Center (contact L.T. Ballance). Selected species were photographed for individual identification purposes, using handheld 35mm cameras and telephoto lenses. Photographs are maintained at Marine Research Centre (contact R. C. Anderson). Acoustic recordings of vocalisations were made using an ITC 1032 hydrophone (flat response from 1Hz to 32kHz and sensitivity of −192dB re 1V/μPa; preamplifier sensitivity of −130dB re 1V/μPa) on 30m of cable and connected to a Digital Audio Tape Recorder. Recordings are held at Alaska Fisheries Science Center/National Marine Mammal Laboratory (contact K. Stafford).

## RESULTS AND DISCUSSION

Survey effort totalled 155.5h (mean = 7.8h/d, SE±0.4) and covered approximately 1,700 linear km on effort. Observation conditions were almost always good to

excellent. Seventy-nine percent (122.7h) of on-effort time was during Beaufort 0-3; 20% (30.7h) during Beaufort 4, and 1% (2.1h) during Beaufort 5.

Cetaceans were abundant. A total of 267 sightings were recorded, 233 of which were on effort. The mean number of sightings per day was 11.8 (SE±1.5, range 0-21) and the mean encounter rate for the entire survey was 13.6 sightings per 100 linear km.

The cetacean community was also diverse, representing a minimum of 16 species: 2 rorquals, the sperm whale (*Physeter macrocephalus*), the dwarf sperm whale (*Kogia sima*), 2 beaked whales and 10 tropical delphinids (Table 1). With perhaps only the exception of the blue whale, these species comprise the typical tropical cetacean community throughout the world (Mullin *et al.*, 1992; Wade and Gerrodette, 1992; Ballance and Pitman, 1998). Although this survey reports the first records in Maldivian waters for Cuvier's beaked whale (*Ziphius cavirostris*, *cf.* Heyning, 1989), Blainville's beaked whale (*Mesoplodon densirostris*, *cf.* Mead, 1989) and *Kogia sima* (*cf.* Caldwell and Caldwell, 1989), all three are pantropical; their occurrence here is not unexpected. The only pantropical cetacean species that were not sighted during the survey were the melon-headed (*Peponocephala electra*) and killer whale (*Orcinus orca*). Both have been observed around the Maldives (R.C. Anderson, unpublished notes) and there are stranding records for each (Dawbin *et al.*, 1970; Pilleri and Gihr, 1974; Anderson, 1990; Leatherwood *et al.*, 1991; Anderson *et al.*, 1999).

**Selected species accounts**

*Blue whale (Balaenoptera musculus)*

This species was rarely encountered. Only four sightings were recorded, all of single individuals (Table 2). Biopsy samples from three individuals were collected and acoustic recordings of three animals were attempted. Subsequent analysis indicated that none were vocalising. It was not possible to confirm the sub-specific identity of any of these four individuals from field observations, and results of genetic analysis of biopsy samples have, to date, been inconclusive (Richard LeDuc, pers. comm.). However, at least two animals had a notably broad head and wide rostrum, indicating that they may have been pygmy blue whales. One of these individuals appeared very thin; the dorsal processes of the vertebral column were clearly visible projecting along the back anterior to the dorsal fin and the lack of tissue lateral to the column resulted in a hollowed-out appearance.

Three of the four animals sighted were diving, each in a localised area, fluking each time. Dive durations (Table 2) are comparable to those recorded from blue whales off Peru with similar behaviour (Donovan, 1984). Although this

Table 1

Species recorded during on-effort periods, listed in decreasing order of number of sightings.

| Species | No. of sightings | School Size | | | Comments |
|---|---|---|---|---|---|
| | | Mean | SE | Range | |
| Spinner Dolphin *Stenella longirostris* | 56 | 50.3 | 10.1 | 8-400 | 6 biopsy samples (4 schools); calves present (min 3 schools); associated with birds and/or tuna (1 school) |
| Bottlenose Dolphin *Tursiops truncatus* | 24 | 6.9 | 1.3 | 1-25 | 2 biopsy samples; calves present (2 schools) |
| Dwarf Sperm Whale *Kogia sima* | 17 | 1.6 | 0.2 | 1-4 | Calves present (3 sightings); includes 2 sightings identified as *Kogia* sp. |
| Unidentified Rorqual | 16 | 1.4 | 0.2 | 1-3 | Most probably Bryde's whales |
| Risso's Dolphin *Grampus griseus* | 16 | 9.9 | 2.1 | 2-35 | Calves present (2 schools) |
| Short-finned Pilot Whale *Globicephala macrorhynchus* | 15 | 14.5 | 2.4 | 4-35 | 6 biopsy samples (3 schools); identification photographs (7 schools); calves present (2 schools); includes 3 sightings identified as *Globicephala* sp. |
| Bryde's Whale *Balaenoptera edeni* | 12 | 3.2 | 1.4 | 1-15 | 8 biopsy samples (4 schools); identification photographs (4 schools); acoustic recordings (4 schools) |
| Striped Dolphin *Stenella coeruleoalba* | 9 | 39.3 | 8.1 | 4-90 | 4 biopsy samples (3 schools); calves present (1 school) |
| Unidentified Beaked Whale | 6 | 2.3 | 0.2 | 2-3 | |
| Spotted Dolphin *Stenella attenuata* | 5 | 50.0 | 11.6 | 15-75 | 3 biopsy samples (3 schools); associated with birds and/or tuna (4 schools) |
| Blue Whale *Balaenoptera musculus* | 4 | 1.0 | 0 | - | 3 biopsy samples (3 sightings); identification photographs (4 animals) |
| Sperm Whale *Physeter macrocephalus* | 3 | 15.7 | 8.1 | 2-30 | Identification photographs (2 schools) |
| Cuvier's Beaked Whale *Ziphius cavirostris* | 2 | 1.5 | 0.5 | 1-2 | |
| Blainville's Beaked Whale *Mesoplodon densirostris* | 2 | 2.5 | 0.5 | 2-3 | |
| *Mesoplodon* sp. | 2 | 2.5 | 0.5 | 2-3 | |
| Pygmy Killer Whale *Feresa attenuata* | 2 | 22.5 | 7.5 | 15-30 | 1 biopsy sample; calves present (1 school) |
| Rough-toothed Dolphin *Steno bredanensis* | 2 | 30 | 10 | 20-40 | 1 biopsy sample; calves present (1 school) |
| False Killer Whale *Pseudorca crassidens* | 1 | 50 | - | - | 1 biopsy sample |
| Fraser's Dolphin *Lagenodelphis hosei* | 1 | 40 | - | - | 3 biopsy samples |

pattern can be indicative of feeding, no other feeding indicators such as defecation were observed. One of these individuals appeared very thin; the dorsal processes of the vertebral column were clearly visible projecting along the back anterior to the dorsal fin.

It had been suspected that blue whales would be more frequently encountered. Anderson *et al*. (1999), concluded from strandings in the Maldives that blue whales are most abundant there during January to April. Alling *et al.* (1991) identified a minimum of 35 individuals around Sri Lanka using photographic identification techniques; some of these animals were resighted in different years. Ballance and Pitman (1998) sighted 13 blue whales and 2 unidentified large rorquals that were probably also blue whales in the Eight Degree Channel north of the Maldives during two separate transits in April 1995. A group of 4-5 blue whales was sighted in deep water west of the Maldives in April, 1983 (Leatherwood *et al.*, 1984). A strong El Niño event was recorded worldwide during 1998. In Maldivian waters that year, there were significant increases in sea surface temperature, widespread coral bleaching and coral mortality (R.C. Anderson, unpublished notes). Further monitoring is needed to determine the status of blue whales around the Maldives, spatial and temporal variation in distribution and abundance and to what extent these patterns are affected by interannual variation in oceanographic conditions and irregular, periodic events such as El Niño.

Table 2

Sighting information for blue whales. (Each sighting represents a single whale.)

| Date | Latitude | Longitude | Mean ± SE dive time (min) |
|---|---|---|---|
| 3 April 1998 | 5°43.8'N | 73°29.4'E | 13.9 ± 0.8 ($n$ = 6) |
| 14 April 1998 | 5°30.1'N | 73°39.8'E | 7.7 ± 0.7 ($n$ = 14) |
| 16 April 1998 | 5°15.1'N | 73°41.8'E | 6.3 ± 0.2 ($n$ = 10) |
| 17 April 1998 | 5°0.3'N | 73°36.0'E | - |

*Bryde's whale (Balaenoptera edeni)*

A dense concentration of this species was encountered in the waters between Felidhoo and Mulaku atolls on 19-20 April (Fig. 1, Table 3). During this time a total of 141.9 linear km was surveyed. Mean encounter rate of Bryde's whales and unidentified rorquals (all of which were probable Bryde's whales) was slightly more than one animal per linear km (mean = 1.2, SE ± 61.6) with a high of 4.5 animals per linear km on one segment. Three-quarters of all our sightings on these two days (28 sightings from a total of 37) were of Bryde's whales or unidentified rorquals.

These whales were diving regularly and not obviously travelling. Although defecation was not observed, it is believed they were feeding. Two whales appeared thin, with the dorsal processes of the vertebral column visible along the back, but most appeared healthy. No calves were sighted in the area.

The taxonomic status of Bryde's whales in the Indian Ocean is unclear. Rice (1998) has concluded that a small form that typically occurs in coastal and shelf waters of the eastern Indian Ocean, the Sunda Shelf and the western Pacific, is referable to *B. edeni*. A larger form is typically found in tropical and warm temperate waters around the world; its description fits *B. brydei*. The animals recorded here are of probably the second, larger form. Genetic analyses of the biopsy samples collected (Richard LeDuc, pers. comm.), as well as catch data records from this area (Y.A. Mikhalev, pers. comm.) support this conclusion. However, because the holotype of *B. edeni* has not been confirmed to be the smaller form, the nominal species name (*B. edeni*) is retained here.

Little is known about the abundance of Bryde's whales in the northwestern Indian Ocean. Between 1963 and 1967 Soviet whaling operations killed 848 in three main areas: the Gulf of Aden, waters around the Seychelles, and near the Maldives (Mikhalev, 1997). The data from this survey indicate that some localised areas around the Maldives may represent important feeding areas for this species. Topographic features, including island archipelagos, are known to be sites of increased productivity due to topographically-induced oceanographic processes which concentrate planktonic prey, with consequent effects on upper trophic levels (e.g. Alldredge and Hamner, 1980; Hamner and Hauri, 1981; Wolanski and Hamner, 1988; Schneider, 1991). Such an effect may have been witnessed here.

Table 3

Sighting information for Bryde's whales.

| Date | Latitude | Longitude | Number of animals |
|---|---|---|---|
| 7 April 1998 | 6°53.3'N | 72°59.8'E | 1 |
| 9 April 1998 | 7°11.0'N | 72°34.7'E | 1 |
| 19 April 1998 | 3°17.3'N | 73°43.4'E | 2 |
| 19 April 1998 | 3°21.0'N | 73°42.8'E | 1 |
| 19 April 1998 | 3°18.2'N | 73°31.5'E | 1 |
| 19 April 1998 | 3°15.4'N | 73°43.4'E | 15 |
| 20 April 1998 | 3°15.4'N | 73°35.1'E | 1 |
| 20 April 1998 | 3°16.4'N | 73°30.4'E | 12 |
| 20 April 1998 | 3°9.2'N | 73°36.2'E | 1 |
| 20 April 1998 | 3°17.8'N | 73°41.7'E | 1 |
| 20 April 1998 | 3°15.4'N | 73°35.2'E | 1 |
| 20 April 1998 | 3°12.7'N | 73°24.3'E | 1 |

*Spinner dolphin (Stenella longirostris)*

This was by far the most abundant and most frequently sighted species, and the cetacean with the largest mean school size (Table 1). Spinner dolphins were often sighted early in the morning entering atoll lagoons and late in the evening exiting from them. A similar behaviour pattern has been described for this species in Hawaii, except that there, dolphins enter bays of high islands to spend the night (Norris and Dohl, 1980).

The spinner dolphin was also the most abundant species seen in a survey of the pelagic western tropical Indian Ocean (Ballance and Pitman, 1998), where school size was significantly higher ($\bar{x}$ = 169.8 dolphins) and diurnal behaviour patterns were different. Recent research has identified significant genetic differences between inshore and offshore populations of what were once considered closely related, or conspecific, to the extent that, for example, offshore populations of cetaceans in different ocean basins may be more closely related than populations in adjacent nearshore waters (e.g. Rosel *et al.*, 1994; Curry and Smith, 1997; Rice, 1998). It is clear that reef-inhabiting spinner dolphins will be subjected to different selective regimes than oceanic populations and character divergence including aspects of behaviour and ecology is to be expected

(e.g. Perrin and Gilpatrick, 1994). This may represent an incipient speciation process; molecular genetic studies would be useful in determining the extent of this divergence.

*Spotted dolphin (Stenella attenuata)*

All sightings of this species were associated with large yellowfin tuna (*Thunnus albacares*, 80% of sightings) or spinner dolphins (40% of sightings). Half of the assemblages with tuna attracted seabirds; one also contained spinner dolphins. Seabirds frequently associate with tuna in the Maldives and local fishermen use flocks to locate tuna, which they capture with hook and line (Anderson, 1996). The association between dolphins and tuna here is restricted to large yellowfin tuna and is much less commonly reported (Anderson and Shaan, 1998). This as-yet-unexplained association between spotted dolphins and yellowfin tuna is a regular feature in the eastern tropical Pacific (Perrin and Hohn, 1994) and is also known to occur in the western tropical Indian Ocean (Ballance and Pitman, 1998).

## CONCLUSIONS

Abundance and diversity of cetaceans around the Maldives were remarkable. In a four-month survey of the western tropical Indian Ocean that covered 9,784 linear km, Ballance and Pitman (1998) recorded 589 sightings comprising a minimum of 21 species. The present study represents only 22% of the survey time and 17% of the survey distance reported in Ballance and Pitman (1998); it also represents 45% of the sightings and 76% of the species recorded during the larger spatial and temporal scale survey.

It is well known that habitat diversity is directly correlated with species diversity. The Maldives, with their 1,200 islands, provide a wide variety of cetacean habitat types within a small geographic area, ranging from sheltered lagoons within atolls to deep waters adjacent to the islands. The monsoon adds another layer of complexity with upstream and downstream eddies affecting productivity, and shifting spatially with season. The archipelago extends for almost 1,000 linear km. Given the limited survey coverage here, the Maldives appear to have extensive cetacean resources.

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