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Diversity and relative abundance of cetaceans in coastal waters off Liberia, based on a geophysical survey

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ABSTRACT

The presence of cetaceans off northwestern Liberia was studied for the first time during a 3D seismic survey from 21 January to 4 May 2009. We documented 126 sightings of cetaceans, ten of which were mixed species assemblages, and confirmed ten species (eight odontocetes and two mysticetes), eight of which were new range state records for Liberia. Habitat covered included the outer continental shelf, slope and offshore trenches (depths ranging 100-3,000 m). Five species, or genera, were frequently encountered (>5 sightings), including (declining order) *Globicephala macrorhynchus, Stenella attenuata, Tursiops truncatus, Balaenoptera* spp. and *Physeter macrocephalus.* Two rorquals were identified as *Balaenoptera brydei*, while seven others remained unidentified. Occasionally encountered species (≤ 4 sightings) included *Stenella longirostris, Steno bredanensis, Grampus griseus, Delphinus* sp. and *Megaptera novaeangliae.* A humpback whale at this southern latitude in late March, and in deep water, raises a question about stock identity. Of nine sightings of *T. truncatus*, four were mixed sightings with pilot whales, pointing to an offshore ecotype. Two small groups of sperm whales were mixed with 100 and 50 unidentified dolphins. The absence of sightings of *Peponocephala electra* and *Lagenodelphis hosei*, common species in Ghanaian waters, is notable.

INTRODUCTION

A regional workshop on the conservation and management of small cetaceans in West Africa, organized in Conakry by Guinea and the CMS/UNEP Secretariat in May 2000, recommended, amongst other priorities, the preparation of supported inventories of cetacean species for each coastal nation. Such information has become available now for many western African nations, as a series of new species records and reviews. However, information on the presence of cetaceans off Liberia, and a supported faunal checklist, are lacking, as is also largely the case for neighbouring Sierra Leone. Sightings of several delphinid species off Côte d'Ivoire were recently documented (de Boer *et al.*, 2016). A review by Perrin and Van Waerebeek (2012) listed only two species of small cetaceans for Liberia, the spinner dolphin *Stenella longirostris* and killer whale *Orcinus orca*. The former is based on a historical *S. longirostris* skull collected in Liberia and archived at the Leiden Natural History Museum, the Netherlands (Broekema, 1983). The latter is based on Hammond and Lockyer (1988, p.26), who mapped a sighting of killer whales off Liberia. However, Phillip Hammond later indicated (*in litt.* to K.V.W., 03 January 2007) that this record was erroneous. Tormosov *et al.* (1980) mapped a sighting of *Delphinus* sp. off Liberia at an unspecified date in 1976-1978. Gray and Van Waerebeek (2011) documented abnormal behaviour and suggested a potentially lethal effect from the seismic operations on a pantropical spotted dolphin *Stenella attenuata.* Finally, a group of 30 false killer whales *Pseudorca crassidens* were reported off Liberia at 04.8°N, 11.4°W on 08 November 1961 (Mörzer-Bruyns, 1969). In summary, authenticated records for Liberia exist only for 2 species, *S. longirostris* and *S. attenuata*, and unsupported reports exist for *P. crassidens* and *Delphinus* sp.
The present paper reports on cetacean observations during a 3D seismic survey offshore Liberia in 2009, which is used to compile the first validated faunal checklist of cetacean diversity in Liberian waters, and estimate relative abundance.

MATERIAL AND METHODS

From 21 January till 4 May 2009 the authors visually surveyed for cetaceans from the R/V *GeoBarents*, a 3D seismic survey vessel, at Blocks LB 15-17, offshore Liberia, around Monrovia. The M/V *Guard Merlin* and *De Vrouwe Marie*, which supported the R/V *GeoBarents* as guard and chase vessels also provided some information. The authors carried out consecutive shifts as marine mammal observers, respectively from 21-Jan till 22-Feb (K.V.W.) and from 27-Feb-09 till 04-May-09 (H.G.), covering a total of 806.28 hours of on-effort survey, over a distance of 5,972.9 km. The exploration area covered a range of marine habitats including the outer continental

shelf, slope and offshore trenches. As a result, depth throughout the survey varied greatly, ranging from approximately 100m to 3,000 m. The large-scale flow of water off Liberia's coast is governed by the Guinea Current, flowing from NW to SE along the Liberian coastline.
The R/V *Geo Barents* towed eight streamers each 6,000 m in length and submerged to a depth of ca. 7 m (+/- 1 m). Two airgun arrays, composing of three gun strings each, were towed approximately 350 m aft of the vessel's stern (Table 1). No formal marine mammal mitigation guidelines and legislation exist in Liberia. However, in view of the potential for negative impacts, the R/V *Geo Barents* voluntarily followed UK's Joint Nature Conservation Committee (JNCC) 'Guidelines for Minimizing Acoustic Disturbance to Marine Mammals from Seismic Surveys' to minimize impacts of underwater noise and other activities. So-called "soft starts", steered by Gun Link 4000 software, initiated an automatic firing sequence. This started with the lowest volume guns first, ramping up sound emission over at least 20 minutes until full power was achieved. Once manually started the soft start ran automatically.

Table 1. Hydrophone streamer parameters

Streamer	
Streamer type	Sercel Seal liquid filled
Number of streamers	8
Streamer separation	100 m
Streamer length	6000 m
Number of groups	8 x 480 (3840)
Group length	12.5 m
Streamer depth	7 m +/- 1 m
Spacing of birds	Every 300 m + extra redundancy at head and tail of streamers

Source	
Source type	Sondera G-gun
Shot interval	25 m flip-flop i.e. 50 m per source
Number Sources	2
Source depth	6 m +/- 1.0 m
Volume	2 x 3400 in^3
Air pressure	2000 psi
Source separation	50 m
Peak-peak	166.4 bar m

Visual survey effort was conducted both by naked eye and using 7 x 50 marine binoculars. Data were recorded on modified versions of JNCC datasheets, supported by photography, distance permitting. A sighting was defined as a visual encounter with a cetacean or a group of interacting cetaceans. In a mixed sighting at least two species occurred together and moved together in a concerted manner, even if some sub-grouping occurred. To determine the relative frequency of encounters of a particular species (%) compared to all other cetacean groups, mixed sightings were split up in their respective species and counted as separate sightings.
Minimal data collected included GPS position, time (UTC), species identification, observed diagnostic characters, group size and group composition (presence of calves, etc.), water depth and environmental conditions. The latter were evaluated by three parameters: sea state (glassy, slight, choppy, rough), swell (low, medium, high) and visibility (poor, moderate, good). Combined, they provided a useful indication of the ability of an observer to find, identify and quantify marine mammal sightings. To assist with species identification and determine group parameters, DSLR cameras were used. Voucher photos and videos were examined and archived independently by both authors. A consensus was discussed in rare occasions when interpretations differed.
All seismic operations were recorded, including the duration of soft start, the attaining of full power and end of gun firing, the length of pre-shoot watches, whether the marine mammals were detected during the pre-shoot watch and if so, what action (if any) was taken. Data on the duration of the soft start, time of full power, and start and end of line was taken from the vessel's Navigation log. Daylight hours were approximately 07:00-19:00 (UTC). Observations were considered ineffective in the period ca. 20 min after sunset until 20 min before sunrise due to insufficient luminosity. Observation efforts were also prioritized during the 30 min pre-firing watch before any soft-start and airgun test. As far as possible, a continuous watch was maintained during line changes and operational downtime. Observations were made from either an outside platform just fore of the bridge 16m above sea surface or from the crane deck behind the bridge. The helideck on the bow was accessed when a 360° view was necessary, or when animals were found bowriding. Speed over ground of the vessel was maintained at about 4 knots.

RESULTS AND DISCUSSION

Total on-effort observation time was 806.28 hr, during which a total of 126 groups of cetaceans were recorded, 10 of which consisted of mixed sightings of two species (Figure 1). To determine the sighting frequency and % prevalence of each species, mixed sightings were split up into their composing species, resulting in a total sample of 136 sightings. Ten cetacean species, two baleen whales and eight odontocetes, were confirmed for Liberia through authenticated sightings, as follows.

Bryde's whale, *Balaenoptera brydei*
Of nine rorqual sightings, two were identified as Bryde's whales because of size, presence of diagnostic three rostral ridges (observed up-close) and consistent dorsal fin shape. The seven others remained classed as 'unidentified rorqual' due to their great distance from the vessel, however several were consistent with Bryde's whale, including behavioural cues (evasive swimming and frequent course changes, irregular surfacings, steep diving). Three groups were associated with small schooling fishes and thought to be feeding. Group size varied 1-2 (median =1). All rorqual sightings occurred at the oceanic side of the continental slope, in waters of 575-1,238 m depth (mean = 870 ±279; n = 7) (Figure 1).

Humpback whale, *Megaptera novaeangliae*
A single, large humpback whale, apparently an adult, was observed on 24 March 2009 in deep water (2,656 m). The date is consistent with known seasonality for the Northeast Atlantic breeding stock occurring around the Cape Verde Islands, *i.e.* January-May (Hazevoet and Wenzel, 2000; Wenzel *et al.*, 2009) or February-June (Cabral and Hazevoet, 2011). However, if a member of this boreal population, then its position (05.83977°N, 11.40485°W) was unusually far south (Figure 2). Alternatively, it could have been an out-of-season humpback whale of austral stock. Numerous humpback whales, many with calves, thought to belong to a South Atlantic stock, overwinter on the continental shelves between Senegal and Guinea and in much of the Gulf of Guinea in September-November (Bamy *et al.*, 2010; Van Waerebeek *et al.*, 2013). However, all of the latter have been encountered in shallow waters (22 - 60 m), in contrast with the deep-water record reported here. In areas with strong year-round upwelling, a limited number of 'unseasonal' humpback whales may dwell in (sub)tropical waters and not undertake an annual poleward migration (e.g. Slijper *et al.*, 1964; Papastavrou and Van Waerebeek, 1998).

Table 2. Encounter rates (number of groups sighted per 100 km observer effort) and relative abundance (number of animals per 100 km) for cetaceans off Liberia in 2009. Species ranked from highest to lowest relative abundance.

Species	Encounter rate (groups /100 km)	Relative abundance (animals /100km)
Stenella longirostris	0.0669	18.230
Stenella attenuata	0.184	15.272
Delphinus sp.	0.0335	7.370
Globicephala macrorhynchus	0.335	6.295
Tursiops truncatus	0.167	3.317
Physeter macrocephalus	0.117	0.518
Steno bredanensis	0.0502	0.820
Grampus griseus	0.0502	0.335
Balaenoptera brydei	0.0335	0.0335
Megaptera novaeangliae	0.0167	0.0167
Delphinidae (unident.)	0.921	-
Balaenoptera spp. (unident.)	0.117	-

Sperm whale, *Physeter macrocephalus*
For the seven groups encountered, group sizes were small and ranged 1-10 (median = 3; mean = 4.43 ±3.41). Two groups of two and five sperm whales were associated with 100 and 50 unidentified dolphins, respectively.

Depths ranged 1908 - 3029 m (median = 2949; mean =2705 ±456). (Figure 3). Stock structure of sperm whales off West Africa has not been studied in any detail, but until further insights, individuals are assumed to belong to the main North Atlantic stock (Dufault *et al.*, 1997).

Short-finned pilot whale, *Globicephala macrorhynchus*
Representing 29% of identified sightings, short-finned pilot whales were the most frequently encountered cetacean (Figure 4). While the species of pilot whale could only twice be ascertained from close observations of the short relative length of the pectoral fins, at these tropical latitudes it is safe to assume that all belonged to the short-finned species. Off West Africa, the long-finned pilot whale *G. melas* (Traill, 1809) has not been documented south of Mauritania (e.g. Nores and Pérez, 1988; Van Waerebeek *et al*., 2000). In 6 of 20 sightings (30 %), schools were mixed with smaller delphinids, typically *Tursiops truncatus* (Figure 4). Although pilot whales and bottlenose dolphins were moving close together, some sub-group separation was maintained. The pilot whales were either resting motionless at the surface ('logging') or were moving very slowly. Such diurnal resting behaviour is consistent with information from other areas and suggest predominant nocturnal feeding. Group sizes ranged 5-45 (mean =18.79 ±12.54, n =19) at depths ranging 500-2795 m (mean = 1344.7 ±823; n =15).

Common bottlenose dolphin, *Tursiops truncatus*
We recorded nine sightings (13 %) of *T. truncatus*, four of these mixed with pilot whales (Figure 4). Groups ranged 5-45 individuals (mean = 19.86 ±16.2; median = 12; n =7). The great depths at which all bottlenose dolphins were found (range 500 - 2900 m; median = 735; mean = 1010 ± 810; n = 8) and their close association with deep-diving pilot whales indicate an offshore ecotype of *T. truncatus.* One group was found at about 93 km from the coast (Figure 4). Rancurel (1964) found undamaged bathypelagic fish in the oesophagus and stomach of *T. truncatus* harpooned off Vridi, Côte d'Ivoire, and after checking data from midwater trawls suggested that it had dived to at least 500 m. Similarly, Cadenat (1959) postulated, from otoliths of bathypelagic fish found in the stomachs of bottlenose dolphins from Senegal, that they were capable of diving to over 200 m depth.
The regional feeding ecology of these offshore animals stands in contrast with that of nearshore, estuarine (e.g. Banc d'Arguin, Archipielago dos Bijagos) and riverine communities (e.g. Casamance and Gambia Rivers) of *T. truncatus*, which are known to feed on littoral fishes such as mullet (*Mugil* spp.) and bonga shad *Ethmalosa fimbriata* during day-time (reviewed in Van Waerebeek *et al*., 2016).

Pantropical spotted dolphin, *Stenella attenuata* (Gray, 1846)
Pantropical spotted dolphins were the second most frequently encountered species off Liberia, accounting for 15.9% of all sightings (Figure 5). Excluding an outlier, a lone dying individual (Gray and Van Waerebeek, 2011), group size ranged 7 - 300 (median = 40; mean = 83.0 ±90.9; n = 9). All sightings occurred over the distant continental slope and in oceanic waters, at depths ranging 520 - 3081 m (median = 2367 m; mean = 2333 ±920; n = 7). The sighting closest to the coast was 39 km.

Spinner dolphin, *Stenella longirostris* (Gray, 1828)
Three sightings of spinner dolphins consisting of an estimated 80, 150 and 800 individuals were encountered exclusively in oceanic water with depths ranging 1,050 - 2,965 m (Figure 6). A fourth sighting formed a mixed species group with *S. attenuata* of 120 dolphins. Very few spinner dolphin specimens are available for study in the region.

Rough-toothed dolphin, *Steno bredanensis* (Lesson, 1828)
Three groups were sighted of 6, 8 and 35 individuals, in deep water (range: 1,310-2,750m) (Figure 7). All were found moving slowly or resting. A rough-toothed dolphin skull, landed at Abidjan port, Cote d'Ivoire, is conserved at the USNM Smithsonian Institution (Cat.no. 0470542).

Risso's dolphin, *Grampus griseus* (Cuvier, 1812)
Three small groups were sighted of 5 - 10 individuals, at depths of 700 - 1,350m. They exhibited mostly slow travel with calm surfacings without any aerial behaviour.

Common dolphin, *Delphinus* sp.
Two groups of common dolphins were sighted, respectively 40 individuals on 9 March 2009 in neritic water (110 m depth) and 400 on 15 March in deeper water (715 m). A small group consisting of some 10 - 15 dolphins bowriding the chase boat was video-recorded by a crew member off Monrovia at an earlier (non-reported) date.

The video was viewed and confirmed by K.V.W. Considering taxonomical and nomenclatural uncertainties raised about *Delphinus* spp. (*e.g.* Pinela *et al.*, 2011; Cunha *et al*., 2015), we refrain from allocating a species epithet until further analysis.

Delphinidae

Unfortunately, an important number of dolphin sightings (55) could not be confidently identified to species, and were listed as 'Delphinidae' mostly due to great distance and a lack of aerial behaviour thus not revealing diagnostic characteristics. Most of these were dolphins with distinct rostra and hence included mainly *Stenella, Tursiops, Delphinus,* and not blackfish.

Table 3. Frequency distribution of unique sightings (Freq); frequency distribution of total number of sightings including mixed ones (Freq total); percent prevalence of all species and species groups sighted (% prev); and percent prevalence of identified species only but including balaenopterids (% prev ID).

Species or species group	Freq.	Freq. total	% prev	% prev ID
Globicephala macrorhynchus	13	20	14.71	27.40
Globicephala macrorhynchus + Delphinidae	2	na	na	na
Globicephala macrorhynchus + T. truncatus	5	na	na	na
Tursiops truncatus	5	10	7.35	13.70
Stenella attenuata	10	11	8.09	15.07
Stenella attenuata + S. longirostris	1	na	na	na
Stenella longirostris	3	4	2.94	5.48
Stenella sp.	3	3	2.21	4.11
Steno bredanensis	3	3	2.21	4.11
Grampus griseus	3	3	2.21	4.11
Delphinus sp.	2	2	1.47	2.74
Physeter macrocephalus	5	7	5.15	9.59
Physeter macrocephalus + Delphinidae	2	na	na	na
Megaptera novaeangliae	1	1	0.74	1.37
Balaenoptera brydei	2	2	1.47	2.74
Balaenopteridae	7	7	5.15	9.59
Delphinidae	55	59	43.38	na
Unidentified small cetacean	2	2	1.47	na
Unidentified whale	2	2	1.47	na
Total	126	136	100	100.00

CONCLUSION

The survey allowed us to authenticate 10 cetacean species for Liberia, including seven delphinids and sperm, Bryde's and humpback whales. New range-state record status applies for eight species. The most frequently encountered species were (in declining order): *G. macrorhynchus*, *S. attenuata*, *T. truncatus*, balaenopterids and *P. macrocephalus* (Table 2). However, *S. longirostris, S. attenuata* and *Delphinus* sp. have the highest relative abundance, due to their large mean group sizes. While 2 rorquals were identified as *B. brydei*, 7 remained listed as *Balaenoptera* sp. due to great distance and out of precaution for potential confusion with Omura's whale *B. omurai* which is present off West Africa (Jung et al., 2015). All these species have a wide distribution in subtropical and tropical waters.

Except for the humpback whale (because of seasonality), all species sighted were expected based on species catalogues for Ghana, Guinea and Côte d'Ivoire. Several other cetaceans most likely occur in Liberian waters, because they are reported off contiguous Côte d'Ivoire (de Boer *et al.*, 2016) and in the subregion, such as the Atlantic spotted dolphin *Stenella frontalis*, Clymene dolphin *Stenella clymene* and false killer whale *Pseudorca crassidens* (Morzer Bruyns, 1969).

The striped dolphin *Stenella coeruleoalba*, was also absent from our records and is unknown from any of the neighbouring coastal nations. A few old specimen records are published for Senegal (reviewed in Van Waerebeek *et al.*, 2000) while Dupuy (1983) reported large schools off Casamance but voucher material is lacking.

Although Clymene dolphins are a probable species off Liberia, the lack of sightings suggest that it is not a common species. Also, only a handful of records exist for Senegal, The Gambia and none for Guinea-Bissau, Guinea and Sierra Leone (Bamy *et al*., 2010; Van Waerebeek *et al.*, 2000). In contrast, eastwards, off Ghana *S.*

clymene is one of the two most commonly captured delphinids (e.g. Ofori-Danson *et al.*, 2013; Van Waerebeek *et al*., 2009, 2010).
A similar situation exists for other pelagic tropical species that are regularly encountered off Ghana (de Boer *et al.*, 2016; Van Waerebeek *et al.*, 2009), such as Fraser's dolphin *Lagenodelphis hosei* and melon-headed whale *Peponocephala electra*, but were not sighted off Liberia and may be uncommon.
Atlantic humpback dolphin *Sousa teuszii*, has not yet been recorded in Liberia, nor further east in Cote d'Ivoire and Ghana (Van Waerebeek *et al*., 2004, 2009; Weir *et al.*, 2011; this paper), despite an unsupported claim by Klinowska (1991). However, shallow nearshore waters, the main habitat of *S. teuszii*, were not surveyed in the present project hence no conclusions can be offered.
De Boer *et al*. (2016) reported dugout canoes fishing off Côte d'Ivoire and Ghana, up to about 100km offshore. If these distances are also indicative for the operational range of small-scale fishermen from Liberia, then all reported species clearly fall within their reach and may become bycatch victims.

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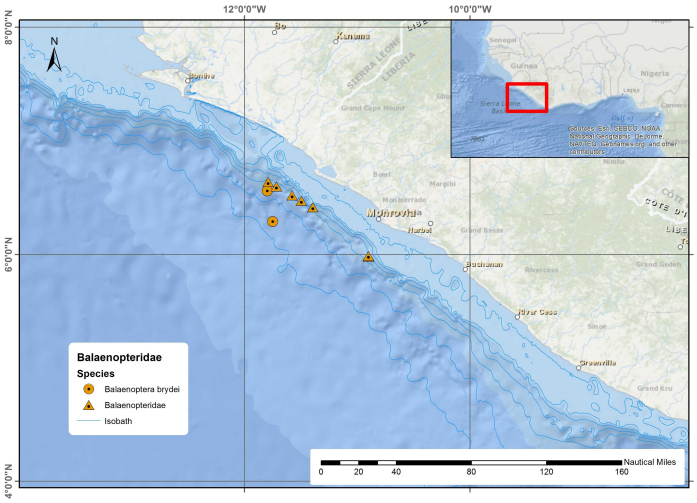

Fig. 1A. *Balaenoptera brydei* (circle); Unidentified Balaenopteridae (triangle)

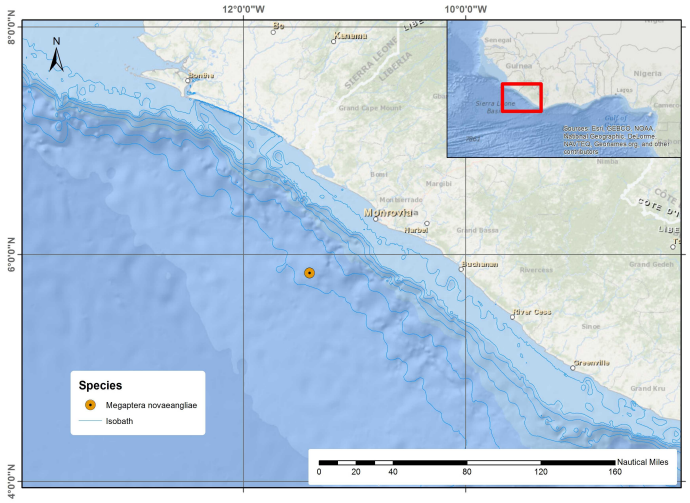

Fig. 1B. *Megaptera novaeangliae* (circle)

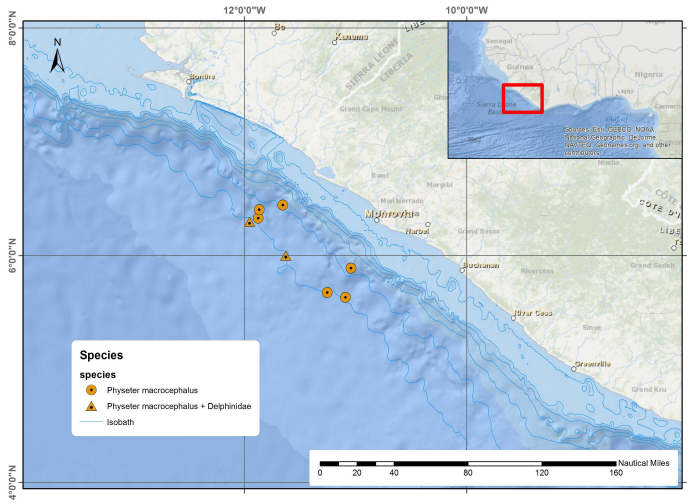

Fig. 1C. *Physeter macrocephalus* (circle); *P. macrocephalus* + Delphinidae (triangle)

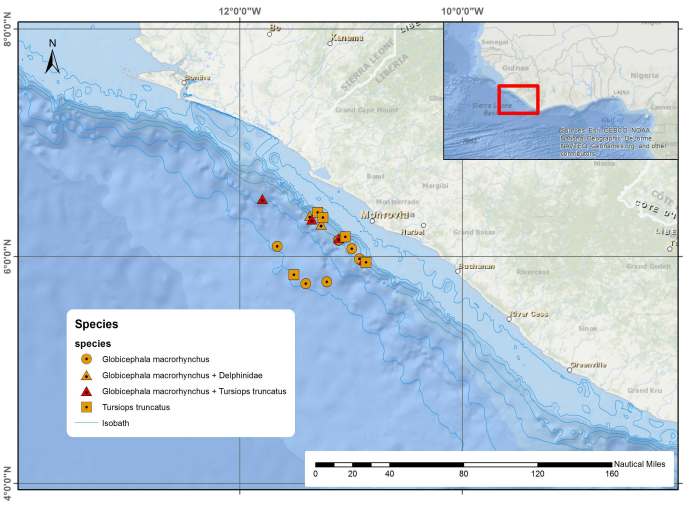

Fig. 1D. *G. macrorhynhus* (circle); *G. macrorhynchus* + *T.truncatus* or Delphinidae (triangles); *T.truncatus* (square)

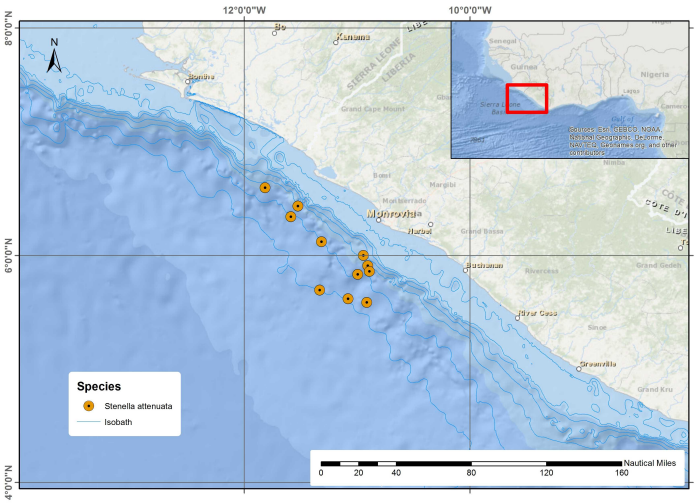

Fig. 1E. *Stenella attenuata* (circle)

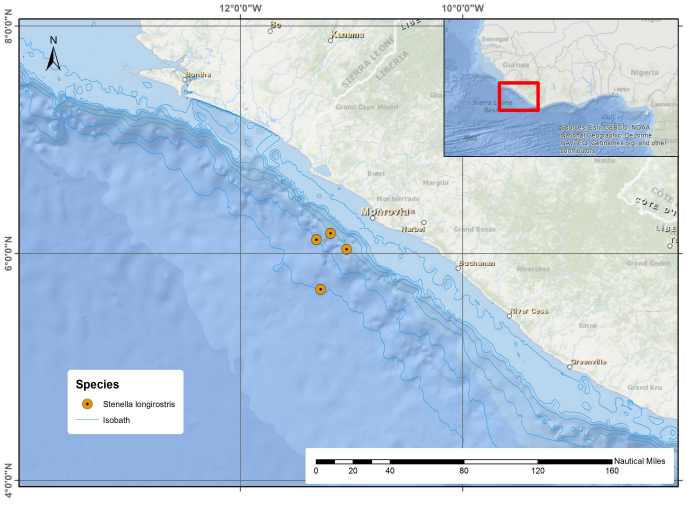

Fig. 1F. *Stenella longirostris* (circle)

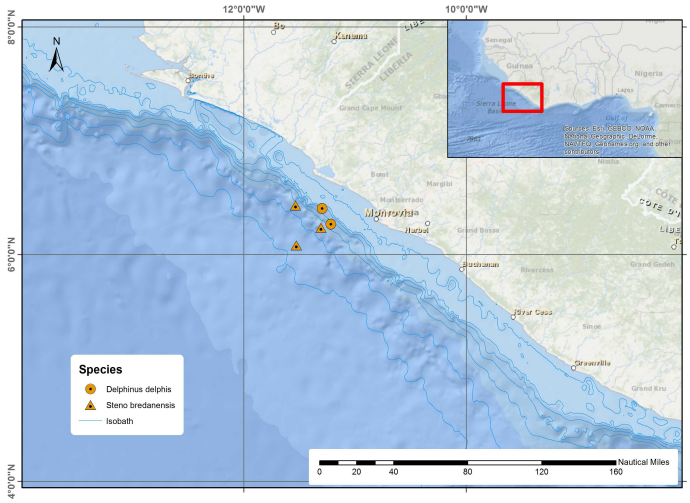

Fig. 1G. *Delphinus* sp. (circle); *Steno bredanensis* (triangle)

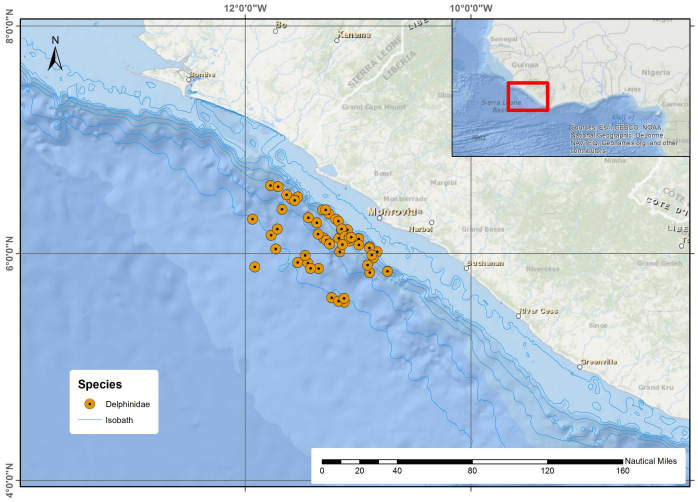

Fig. 1H. Delphinidae -unid. (circle)