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Heard but not seen: Occurrence of *Kogia* spp. along the western North Atlantic shelf break

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The two species in the family Kogiidae, the pygmy (*Kogia breviceps*) and dwarf (*K. sima*) sperm whales, are found worldwide in tropical and temperate waters (Jefferson *et al*. 1993). These cryptic species (hereafter referred to as *Kogia*) are difficult to detect during visual surveys due to their small size and inconspicuous surfacing behavior (McAlpine 2009). When sighted, both species are found in small groups (Jefferson *et al*. 1993) and avoid vessels (Würsig *et al*. 1998). They do not show their flukes when they dive (McAlpine 2009) and sometimes merely sink from the surface (Willis and Baird 1998). Their blow is seldom visible, and they often lie motionless at the surface (Leatherwood *et al*. 1976, McAlpine 2009). For all of these reasons, these two species are difficult to detect in anything other than very calm seas (Jefferson *et al*. 1993, Baird 2005). As a result of their inconspicuous

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behavior, Barlow (1999) estimated a very low probability (0.35) of detecting *Kogia* along a trackline during traditional visual line transect surveys.

Both species of *Kogia* are generally found in waters of the shelf break and continental slope off the United States (Davis *et al.* 1998, Baumgartner *et al.* 2001, Scott *et al.* 2001, Garrison *et al.* 2010). In the Gulf of Mexico, Baumgartner *et al.* (2001) recorded sightings most frequently in water depths between 400 and 1,000 m, with some sightings extending into much deeper waters (up to 3,500 m). Similarly, around the main Hawaiian Islands, *Kogia* were found in waters between 450 and 3,200 m, with an average depth between 1,400 and 1,600 m (Baird 2005).

NOAA stock assessment surveys between 1992 and 2011 yielded relatively few sightings of *Kogia* (33) in shelf break and slope waters between Virginia and Florida (Atlantic coast) (Halpin *et al.* 2009; Diaz 2011; Palka 2011; Garrison 2013*a, b*; Palka 2013*a, b, c*; Josephson 2015). Despite the low number of sightings, *Kogia* strand frequently along beaches of the southeastern United States. For example, between 1978 and 1987, Odell (1991) documented that *Kogia* was the second most frequently stranded cetacean taxon, after bottlenose dolphins (*Tursiops truncatus*), from North Carolina to Texas. During the period covered by the present study (2007–2015), 17 strandings of *Kogia* occurred in Virginia, 81 in North Carolina, and 112 on the Atlantic coast of Florida (NOAA National Stranding Database), without any apparent seasonal pattern. Byrd *et al.* (2014) documented that *Kogia* was the third most frequently stranded cetacean taxon in North Carolina from 1997 to 2008. The large number of strandings in these states suggests that *Kogia* are a common component of the Atlantic cetacean fauna, despite the fact that these species are seldom detected during visual surveys in these waters (Garrison *et al.* 2010). This mismatch between the number of strandings and number of visual sightings is almost certainly a result of their cryptic nature.

In the present study, we analyzed detections of *Kogia* using passive acoustic monitoring (PAM) in shelf break waters of the western North Atlantic. Passive acoustic monitoring is a useful way to evaluate the distribution of many cetacean species (Mellinger *et al.* 2004, Philpott *et al.* 2007, Stafford *et al.* 2007, Verfuß *et al.* 2007). PAM generates a long-term record unmatched by visual surveys and can provide information about patterns of daily and seasonal usage of areas, as long as animals are vocally active. Passive acoustic methods hold several advantages over visual surveys, including the ability to monitor during periods of inclement weather and poor visibility (including periods of high sea states and darkness), and in remote locations. Passive acoustic methods have been successful in monitoring rare species, such as the North Pacific right whale (*Eubalaena japonica*) (Munger *et al.* 2008), and those with a cryptic nature, such as beaked whales (Baumann-Pickering *et al.* 2014). The purpose of our study, therefore, was to compare detections of *Kogia* between visual survey and PAM methods along the U.S. Atlantic coast.

We compared the results of visual surveys and PAM of *Kogia* in four geographic locations: (1) Norfolk Canyon, Virginia; (2) Cape Hatteras, North Carolina; (3) Onslow Bay, North Carolina; and (4) Jacksonville, Florida (Fig. 1). The surveys and PAM program are part of a large scale effort to describe patterns of occurrence and distribution of marine mammals for the U.S. Navy (*e.g.*, Read *et al.* 2014).

We conducted shipboard visual surveys in two modes: line transect surveys and photo-identification and biopsy sampling effort, which did not follow predetermined tracklines. During both survey modes, vessels traveled between 8 and 15 knots and two observers scanned from straight ahead to 90° abeam either side of the trackline. All observations were made by naked eye and 7×50 binoculars. We

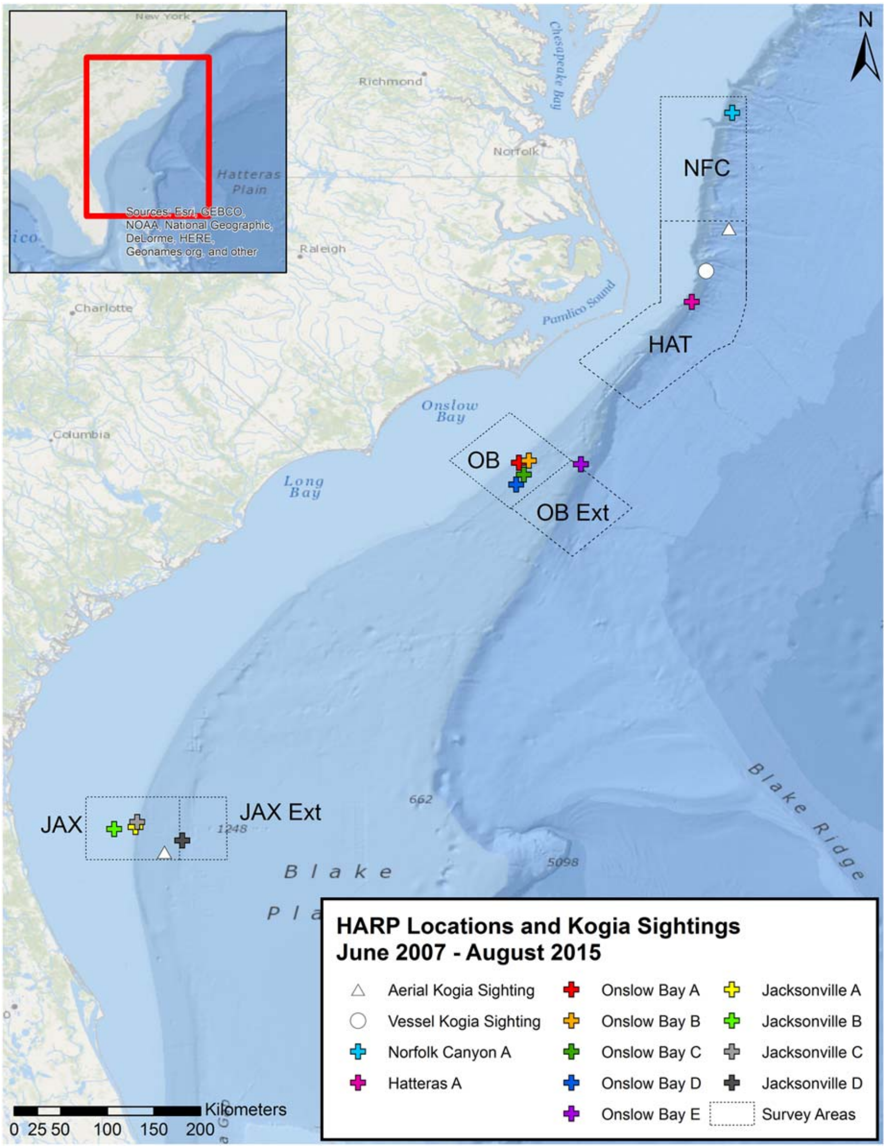

Figure 1. Locations of visual survey areas, HARP deployments, and three visual detections of *Kogia* spp. between June 2007 and August 2015. NFC = Norfolk Canyon study site, HAT = Cape Hatteras study site, OB = main Onslow Bay study site, OB Ext = extended Onslow Bay study site, JAX = main Jacksonville study site, and JAX Ext = extended Jacksonville study site.

obtained photographs with digital SLR cameras to confirm species identity. Aerial surveys were flown in a Cessna 337 Skymaster (Orion Aviation, Siler City, NC) at 185 km/h and at 305 m altitude. Two observers (one port and one starboard) monitored separate sides of the plane. For all cetacean sightings, the plane broke from the

Table 1. Shipboard and aerial visual survey effort for each location. See Figure 1 for more information on survey locations.

			Visual survey effort (km)	
Location	Start survey	End survey	Shipboard	Aerial
Norfolk Canyon	January 2015	August 2015[a]	0	2,381
Cape Hatteras	July 2009	August 2015[a]	6,177	27,977
Onslow Bay (main)	June 2007	August 2015	7,155	48,635
Onslow Bay (extended)	August 2010	March 2011	0	524
Jacksonville (main)	July 2009	August 2015[a]	5,131	82,032
Jacksonville (extended)	April 2015	August 2015[a]	0	859

[a]Represents end of data collection reported here but not the end of survey effort.

trackline to circle above the animal(s), and photographs were taken for species identification using either a Canon 40D or Canon 70D equipped with a 100–400 mm image stabilizer lens. Aerial and shipboard surveys were commonly conducted in low Beaufort Sea States (0–4). Visual survey effort for all locations is summarized in Table 1.

In the PAM component of this study, we employed High-frequency Acoustic Recording Packages (HARPs; Wiggins and Hildebrand 2007) mounted on the sea floor and sampling at 200 kHz in all four locations (Fig. 1, Table 2). The data-logging system had an effective bandwidth of 0.01–100 kHz and included a 16-bit analog-to-digital converter and an ITC-1042 hydrophone (International Transducer Corporation), with a frequency response from 10 Hz to 100 kHz and sensitivity of −200 dB re: 1 V/μPa (± 2 dB). The hydrophone was suspended between 10 and 22 m above the seafloor, depending on mooring style. In Norfolk Canyon and Cape Hatteras, HARPs were deployed at a single site, at depths of at least 850 m (Table 2). In Onslow Bay and Jacksonville, HARPs were deployed at multiple sites, some shallow (between 35 and 340 m) and others deep (810–980 m) (Fig. 1, Table 2). The duty cycles of the HARPs varied from recording for 5 min every 15 min to recording continuously (Table 2).

K. breviceps produce high-frequency, narrow-band clicks with peak frequencies around 125–130 kHz and minimum frequencies as low as 60 kHz (Marten 2000, Madsen *et al*. 2005). *K. sima* also produce similar high-frequency, narrow-band clicks (Merkens *et al*. 2018). The HARPs were unable to capture the full frequency range of the clicks of these species, but the portion of the click energy below 100 kHz was recorded and some energy above 100 kHz may have been aliased down and thus recorded as well (Fig. 2, 3 provide more information on the *Kogia* clicks detected in the HARP records). All other species of odontocetes found in these areas produce clicks with lower minimum frequencies, with the exception of harbor porpoises (*Phocoena phocoena*), which produce clicks with shorter interclick intervals (ICIs), on average, (with peaks of consistent ICIs between 40 and 60 ms: Villadsgaard *et al*. 2007, Verfuß *et al*. 2009) than those found in this study (Fig. 3). Thus, we considered all clicks without energy below 60 kHz to have been produced by *Kogia*.

We detected *Kogia* clicks in the HARP recordings in one of two ways: (1) manually, by scanning 30 min long-term spectral averages (LTSAs) generated in Triton

Table 2. HARP deployment sites, recording dates, depths, duty cycles, number of *Kogia* spp. click detections (with a detection defined by clicks separated by no more than 1 min), and detection method. All HARPs sampled at 200 kHz. Depth classification was "deep" if >800 m, otherwise "shallow." See Figure 1 for more information on HARP locations.

Geographic location	Site	Recording start date	Recording end date	# Days recorded	Depth (m)	Depth classification	Duty cycle (min on/off)	# *Kogia* spp. detections	Detection method
Norfolk Canyon	A	19 Jun 2014	5 Apr 2015	290	980	deep	continuous	85	multistep
Cape Hatteras	A	15 Mar 2012	11 Apr 2012	28	950	deep	continuous	4	multistep
Cape Hatteras	A	9 Oct 2012	9 May 2013	212	970	deep	continuous	78	multistep
Cape Hatteras	A	29 May 2013	15 Mar 2014	290	970	deep	continuous	126	multistep
Cape Hatteras	A	9 May 2014	11 Dec 2014	217	850	deep	continuous	71	multistep
Onslow Bay	A	10 Oct 2007	16 Jan 2008	99	160	shallow	5/5[a]	4	multistep
Onslow Bay	B	30 May 2008	10 Sep 2008	104	230	shallow	5/5	5	multistep
Onslow Bay	A	24 Apr 2009	9 Aug 2009	108	170	shallow	5/5	1	multistep
Onslow Bay	A	8 Nov 2009	24 Feb 2010	109	170	shallow	5/10	4	multistep
Onslow Bay	C	8 Nov 2009	20 Apr 2010	64	340	shallow	5/10	6	multistep
Onslow Bay	A	30 Jul 2010	3 Mar 2011	217	170	shallow	5/5	12	multistep
Onslow Bay	D	30 Jul 2010	24 Feb 2011	210	340	shallow	5/5	11	multistep
Onslow Bay	E	19 Aug 2011	1 Dec 2011	105	950	deep	5/5	80	multistep
Onslow Bay	E	14 Jul 2012	2 Oct 2012	81	910	deep	5/5	37	multistep
Onslow Bay	E	24 Oct 2012	30 Jun 2013	250	850	deep	5/5	749	multistep
Jacksonville	A	2 Apr 2009	25 May 2009	54	80	shallow	5/10	0	manual
Jacksonville	B	2 Apr 2009	5 Sep 2009	157	40	shallow	5/10	0	manual
Jacksonville	A	16 Sep 2009	15 Dec 2009	91	80	shallow	5/10	0	manual
Jacksonville	A	22 Feb 2010	30 Jul 2010	159	90	shallow	5/10	0	manual
Jacksonville	B	9 Mar 2010	19 Aug 2010	164	40	shallow	5/10	0	manual
Jacksonville	A	26 Aug 2010	25 Jan 2011	153	90	shallow	5/10	0	manual
Jacksonville	B	27 Aug 2010	1 Feb 2011	160	40	shallow	5/10	0	manual
Jacksonville	A	1 Feb 2011	14 Jul 2011	164	90	shallow	5/10	0	manual
Jacksonville	B	2 Feb 2011	14 Jul 2011	163	40	shallow	5/10	0	manual
Jacksonville	C	13 May 2013	20 Jun 2013	39	90	shallow	continuous	0	manual
Jacksonville	C	17 Feb 2014	23 Aug 2014	188	90	shallow	continuous	0	manual
Jacksonville	D	23 Aug 2014	29 May 2015	279	810	deep	continuous	210	multistep

[a]Represents the initial duty cycle but instrument recorded continuously starting 1 January 2008.

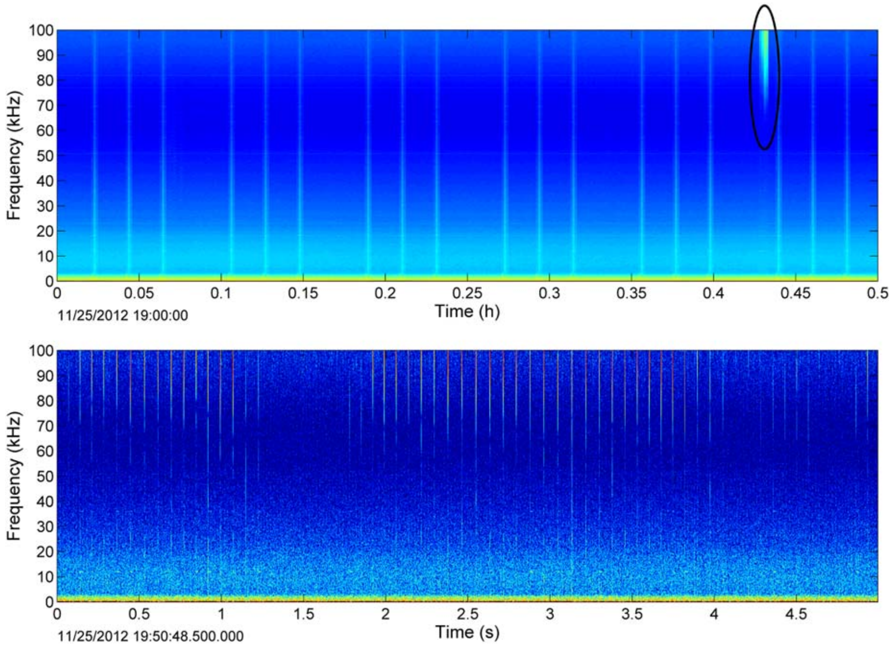

Figure 2. Long-term spectral average (top) and spectrogram (bottom) showing the lower frequencies of *Kogia* clicks as recorded by the final Onslow Bay Site E HARP. The black circle in the top panel indicates *Kogia* clicks.

(Wiggins and Hildebrand 2007); or (2) with a custom-built, Matlab-based, multistep detector (see Table 2 for details on which method was used for each deployment). The multistep detector first identified acoustic encounters of *Kogia* in the acoustic data using a Teager-Kaiser energy click detector (Roch *et al*. 2011) and an expert system (based on selecting clicks with peak frequency >70 kHz). All presumed *Kogia* acoustic encounters were reviewed in a second analysis stage to remove false detections and apply a consistent detection threshold. Individual echolocation signals were automatically detected, this time using an energy threshold method during time periods of verified *Kogia* acoustic encounters defined during the procedure described above. Detections were selected for inclusion when the signal in a 70–99 kHz band exceeded a threshold of 116 dB pp re: 1 μPa. We then manually reviewed the acoustic encounters using comparative panels showing long-term spectral average, received level, and ICI of individual clicks over time, as well as spectral and waveform plots of selected individual signals. Within each encounter, we removed false detections by manual editing. False detections, identified by inappropriate spectral amplitude, ICI, or waveform, included signals identified as being from sonars, sperm whales, or delphinids.

During shipboard and aerial visual surveys between June 2007 and August 2015, we detected 19 species of cetaceans and two groups (*Kogia* spp. and *Mesoplodon* spp.) classified only to genus (Table 3). In almost 2,500 cetacean sightings from these shipboard and aerial surveys, we recorded only three sightings of *Kogia*. The shipboard surveys detected *Kogia* only once, off Cape Hatteras at a depth of 1,558 m, and the aerial survey team recorded only two *Kogia* sightings, one off Cape Hatteras

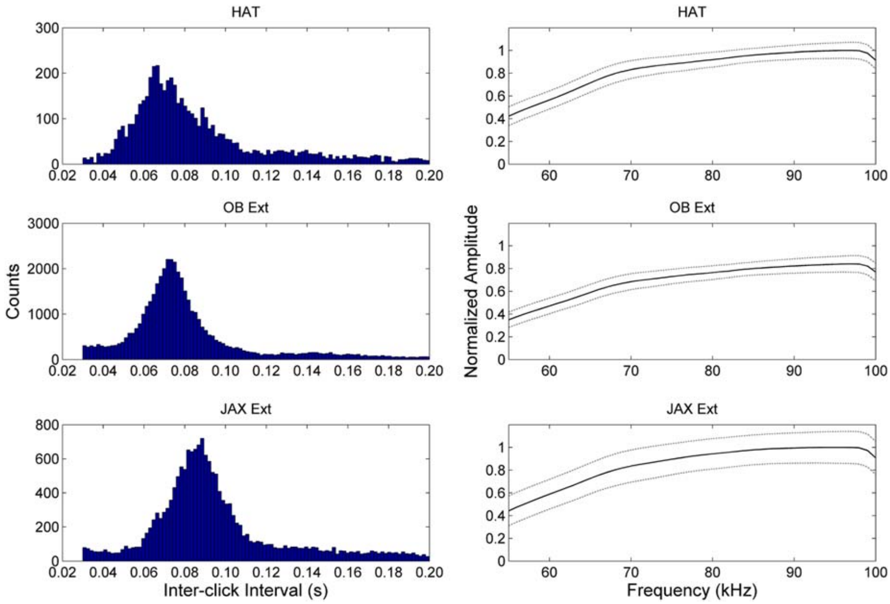

Figure 3. Interclick interval distributions (left panels) and mean spectra with standard deviation (right panels) of clicks classified as *Kogia* for the deep water sites (top to bottom: Cape Hatteras study site [HAT], extended Onslow Bay study site [OB Ext], and extended Jacksonville study site [JAX Ext]). Note different scales for *y*-axes for interclick interval distributions.

(1,928 m) and the other off Jacksonville (548 m) (Fig. 1). There were no sightings of harbor porpoises.

We made 1,483 acoustic detections of *Kogia* on HARPs in the four locations (Table 2). The high frequency clicks produced by *Kogia* do not propagate far, so the animals producing these clicks were likely within 500–600 m of the recorders. Thus, the locations of the recorders provide information on the water depths of the animals producing these clicks. We made no detections at any of the shallow Jacksonville sites (A, B, C) and only 43 total detections in seven deployments at the shallow Onslow Bay sites (A, B, C, D) (Table 2). However, whenever HARPs were deployed in deep water (>800 m at all four locations), *Kogia* were consistently detected (Fig. 4). We observed no obvious diel pattern in detection of *Kogia* clicks in either shallow or deep sites (Fig. 4).

These results lead us to three main conclusions: (1) *Kogia* show a habitat preference for deeper waters in the western North Atlantic, (2) *Kogia* are relatively common in shelf break and slope waters of the western North Atlantic between Virginia and Florida, and (3) *Kogia* are not readily available to visual surveys in this region.

Our study underscores the limitations of visual surveys for *Kogia* and highlights the value of PAM for describing the occurrence and distribution of this cryptic genus. The number of acoustic detections may have been reduced due to the sampling rate of the HARPs, but our acoustic records in deeper water contained hundreds of detections, indicating that animals of this genus were relatively common in the deeper parts of our study area. As PAM technology continues to advance,

Table 3. Number of visual sightings of species in the Norfolk Canyon, Cape Hatteras, Onslow Bay, and Jacksonville survey areas between June 2007 and August 2015. For aerial surveys in Onslow Bay and Jacksonville, the first number is the number of visual sightings in the main survey area, and the second number is the number of sightings in the extended survey area.

	Norfolk Canyon	Cape Hatteras		Onslow Bay		Jacksonville	
Species	Aerial	Aerial	Vessel	Aerial	Vessel	Aerial	Vessel
Balaenoptera acutorostrata	—	6	—	9/—	—	9/—	—
Balaenoptera physalus	—	5	3	1/—	—	—/—	—
Delphinus delphis	4	18	28	1/—	—	—/—	—
Eubalaena glacialis	—	—	—	—/—	—	2/—	1
Globicephala macrorhynchus	2	111	201	9/—	4	17/1	3
Grampus griseus	1	22	8	8/—	7	51/1	4
Kogia spp.	—	1	1	—/—	—	1/—	—
Lagenodelphis hosei	—	1	—	—/—	—	—/—	—
Megaptera novaeangliae	1	8	—	1/—	—	3/—	—
Mesoplodon europaeus	—	5	—	—/—	—	—/—	—
Mesoplodon spp.	—	24	1	—/4	2	—/—	—
Peponocephala electra	—	2	—	—/—	—	—/—	—
Physeter macrocephalus	1	26	14	—/—	—	2/—	—
Stenella attenuata	—	—	—	—/—	—	1/—	
Stenella clymene	—	7	—	—/—	—	—/—	—
Stenella coeruleoalba	3	5	—	—/—	—	—/—	—
Stenella frontalis	8	38	19	68/—	52	333/—	91
Stenella longirostris	—	1	—	—/—	—	—/—	—
Stenella/*Delphinus* mix	—	—	1	—/—	—	—/—	—
Steno bredanensis	—	1	—	3/—	1	8/—	—
Tursiops truncatus	8	189	197	148/1	89	410/3	88
Tursiops/*Stenella* mix	—		1	—/—	—	—/—	1
Ziphius cavirostris	—	40	34	—/—	—	—/—	—

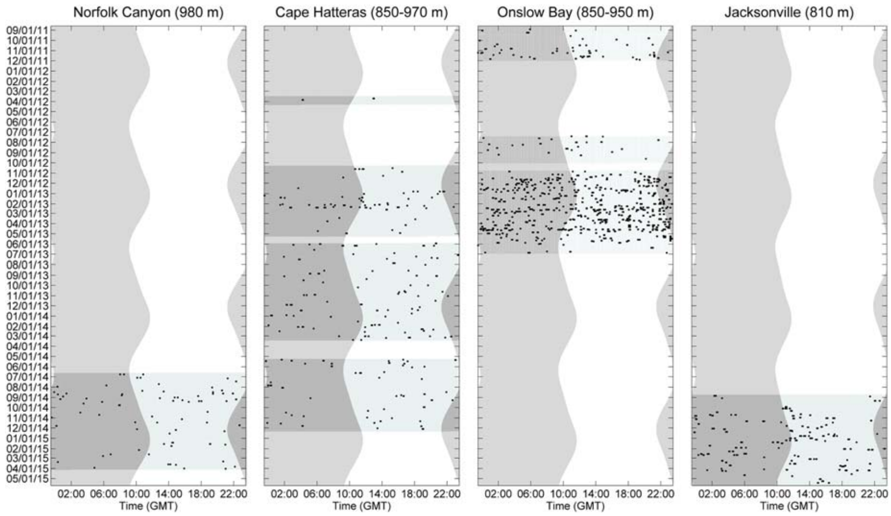

Figure 4. Acoustic click detections presumed to be *Kogia* spp. from the deep-water (>800 m) HARP recordings at the four survey locations (left to right: Norfolk Canyon, Cape Hatteras, Onslow Bay, and Jacksonville). Black markings represent the acoustic detections. Vertical gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil), and horizontal gray shading indicates effort. All recordings were made continuously except for those in Onslow Bay, which recorded for 5 min of every 10 min.

particularly with longer battery life and increased data storage capacity, it will be possible to record for long periods at higher sampling rates, which will yield more detailed observations of the distribution and occurrence of this genus.

Our finding of the occurrence of *Kogia* primarily in deeper waters agrees with scattered sighting records from previous visual surveys. Sightings recorded during NOAA stock assessment surveys from 1992 to 2011 from Virginia to Florida ranged in depth from 700 to 4,500 m, but 28 of 33 sightings were made in waters deeper than 2,000 m (Halpin *et al*. 2009; Diaz 2011; Palka 2011; Garrison 2013*a, b*; Palka 2013*a, b, c*; Josephson 2015). We did not place acoustic recorders in depths greater than 980 m, so we cannot comment on the occurrence of this genus in deeper waters.

Given the numerous acoustic encounters of *Kogia* in the deeper portions of our study areas, we were surprised to have recorded so few sightings in our visual surveys. Barlow's (1999) estimation of the trackline detection probability of 0.35 was generated using data from surveys aboard large NOAA vessels—much larger than the relatively small vessels (all <15 m in length) used in our study. Observers on these large research vessels typically search for cetaceans with high-powered binoculars from a flying bridge high above the water's surface. The results described here strongly suggest that the detection probability from our small vessels was considerably lower than 0.35, perhaps because *Kogia* reacted to our survey vessels before we could detect their presence.

There are several possible biases in our comparisons between the results of visual surveys and PAM. First, we conducted relatively little visual survey effort in three of the four sites where most of the acoustic detections occurred—Norfolk Canyon, the extended Onslow Bay site, and the extended Jacksonville site. However, in Cape Hatteras, we generated a significant amount of visual survey effort, from both shipboard and aerial platforms, with which to compare to the PAM record. Despite this, we recorded only two visual sightings of *Kogia* in the Cape Hatteras survey area between June 2007 and August 2015 in more than 34,000 km of combined survey effort. We recorded a large number of sightings of other species (Table 3), including deep-diving beaked whales (*Ziphius* and *Mesoplodon*), during these surveys. This paucity of sightings, when combined with numerous acoustic detections in Cape Hatteras, supports the cryptic nature of *Kogia* and emphasizes that a lack of sightings is not representative of the absence of this genus in a particular area.

Second, it is possible that some of the clicks assigned to *Kogia* in Norfolk Canyon and Cape Hatteras were produced by harbor porpoises, the only other species in this region known to produce such high-frequency calls. During the winter and early spring, harbor porpoises have been observed as far south as Nags Head, North Carolina (Blaylock 1985, Read *et al*. 1995, Waring *et al*. 2007). During our study period, a few harbor porpoises stranded as far south as Bald Head Island, North Carolina, although only five out of 120 North Carolina harbor porpoise strandings occurred south of Cape Hatteras (NOAA National Stranding Database). Harbor porpoises produce high-frequency, narrow-band clicks with peak frequencies around 130 kHz and with most energy between 100 and 160 kHz (Møhl and Anderson 1973, Au 1997). The harbor porpoise clicks would likely have to be aliased down below the Nyquist frequency to be recorded, but without the full bandwidth of the click, it is difficult to distinguish the clicks of *Kogia* from harbor porpoises in the HARP recordings used in the present study. However, harbor porpoises have been found to produce clicks with shorter peak ICIs (40–60 ms: Villadsgaard *et al*. 2007, Verfuß *et al*. 2009) than the clicks we describe here, which had ICIs that peaked between 64 and 84 ms (Fig. 3). Also tempering the possibility of misclassification is the fact that there were no obvious seasonal patterns to the detection of clicks in any of the data sets (Fig. 4). If these clicks were produced by harbor porpoises, we would expect a seasonal increase in the number of acoustic detections in winter and early spring (Virginia: S. Barco;[2] North Carolina: see Byrd *et al*. 2014), and a significant reduction in their occurrence during summer and fall. In addition, harbor porpoises are distributed mainly in coastal waters over the continental shelf (Barlow 1988, Read and Westgate 1997) and are much less likely to be found at the depths of the deep HARPs, where most *Kogia* detections occurred. The animals would have to be capable of diving to near the depth of the HARPs, which provides further support that the clicks were not produced by the more shallow-diving harbor porpoise (Westgate *et al*. 1994, Otani *et al*. 1998).

We conclude that *Kogia* are more common along the Atlantic shelf break and slope waters than suggested by the visual survey record. We base this conclusion on their frequent occurrence in PAM records, together with the relative frequency with which they strand in this area. More specifically, PAM records indicate that *Kogia* are common in deeper waters of the western North Atlantic between Virginia and Florida. The very small number of records of this genus made during extensive visual surveys could lead to the erroneous conclusion that this genus is uncommon, rather than a regular component of the cetacean fauna in this region. Our use of PAM allowed us to document a more accurate picture of the presence of *Kogia*, and

[2]Personal communication from Susan Barco, Virginia Aquarium & Marine Science Center Foundation, Virginia Beach, Virginia, August 2016.

we recommend the use of this technique to describe the presence of these and other cryptic species in other areas.

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Literature Cited

Au, W. W. L. 1997. Echolocation in dolphins with a dolphin-bat comparison. Bioacoustics 8:137–162.

Baird, R. W. 2005. Sightings of dwarf (*Kogia sima*) and pygmy (*K. breviceps*) sperm whales from the main Hawaiian Islands. Pacific Science 59:461–466.

Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimation for California, Oregon, and Washington: I. Ship surveys. Fishery Bulletin 86:417–432.

Barlow, J. 1999. Trackline detection probability for long-diving whales. Pages 209–221 *in* G. W. Garner, S. C. Amstrup, J. L. Laake, B. F. J. Manly, L. L. McDonald and D. G. Robertson, eds. Marine mammal survey and assessment methods. Balkema Press, Rotterdam, The Netherlands.

Baumann-Pickering, S., M. A. Roch, R. L. Brownell, Jr., *et al*. 2014. Spatio-temporal patterns of beaked whale echolocation signals in the North Pacific. PLOS ONE 9:e86072.

Baumgartner, M. F., K. D. Mullin, L. N. May and T. D. Leming. 2001. Cetacean habitats in the northern Gulf of Mexico. Fishery Bulletin 99:219–239.

Blaylock, R. A. 1985. The marine mammals of Virginia with notes on identification and natural history. Virginia Institute of Marine Sciences Education Series 35.

Byrd, B. L., A. A. Hohn, G. N. Lovewell, *et al*. 2014. Strandings as indicators of marine mammal biodiversity and human interactions off the coast of North Carolina. Fisheries Bulletin 112:1–23.

Davis, R. W., G. S. Fargion, N. May, *et al*. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. Marine Mammal Science 14:490–507.

Diaz, G. 2011. NOAA Southeast Fishery Science Center (SEFSC) Commercial Pelagic Observer Program (POP) Data. Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/103151496) on 29 June 2016.

Garrison, L. P., A. Martinez and K. Maze-Foley. 2010. Habitat and abundance of cetaceans in Atlantic Ocean continental slope waters off the eastern USA. Journal of Cetacean Research and Management 11:267–277.

Garrison, L. 2013*a*. SEFSC Atlantic surveys, 1992. Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/3) on 29 June 2016.

Garrison, L. 2013*b*. SEFSC Atlantic surveys, 1998 (3). Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/1) on 29 June 2016.

Halpin, P. N., A. J. Read, E. Fujioka, *et al*. 2009. OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. Oceanography 22:104–115.

Jefferson, T. A., S. Leatherwood and M. A. Webber. 1993. FAO species identification guide. Marine mammals of the world. Rome, Italy.

Josephson, B. 2015. AMAPPS Northeast Shipboard Cruise Summer 2011. Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/1269) on 29 June 2016.

Leatherwood, S., D. K. Caldwell and H. E. Winn. 1976. Whales, dolphins, and porpoises of the Western North Atlantic: A guide to their identification. U.S. Department of Commerce, NOAA Technical Report NMFS CIRC-396. 176 pp.

Madsen, P. T., D. A. Carder, K. Bedholm and S. H. Ridgway. 2005. Porpoise clicks from a sperm whale nose—convergent evolution of 130 kHz pulses in toothed whales? Bioacoustics 15:195–206.

Marten, K. 2000. Ultrasonic analysis of pygmy sperm whale (*Kogia breviceps*) and Hubbs' beaked whale (*Mesoplodon carlhubbsi*) clicks. Aquatic Mammals 26:45–48.

McAlpine, D. F. 2009. Pygmy and dwarf sperm whales *Kogia breviceps* and *K. sima*. Pages 936–938 *in* W. F. Perrin, B. Würsig, J. G. M. Thewissen, eds. Encyclopedia of marine mammals. 2nd edition. Academic Press, San Diego, CA.

Mellinger, D. K., K. M. Stafford and C. G. Fox. 2004. Seasonal occurrence of sperm whale (*Physeter macrocephalus*) sounds in the Gulf of Alaska, 1999–2001. Marine Mammal Science 20:48–62.

Merkens, K., D. Mann, V. M. Janik, D. Claridge, M. Hill and E. Oleson. 2018. Clicks of dwarf sperm whales (*Kogia sima*). Marine Mammal Science. Available at https://doi.org/10.1111/mms.12488.

Møhl, B., and S. Andersen. 1973. Echolocation: High-frequency component in the click of the harbour porpoise (*Phocoena ph. L.*). Journal of the Acoustical Society of America 54: 1368–1372.

Munger, L. M., S. M. Wiggins, S. E. Moore and J. A. Hildebrand. 2008. North Pacific right whale (*Eubalaena japonica*) seasonal and diel calling patterns from long-term acoustic recordings in the southeastern Bering Sea, 2000–2006. Marine Mammal Science 24: 795–814.

Odell, D. K. 1991. A review of the Southeastern United States Marine Mammal Stranding Network: 1978–1987. Pages 19–23 *in* Marine mammal strandings in the United States. NOAA Technical Report NMFS 98. Proceedings of the Second Marine Mammal Stranding Workshop, Miami, FL.

Otani, S., Y. Naito, A. Kawamura, M. Kawasaki, S. Nishiwaki and A. Kato. 1998. Diving behavior and performance of harbor porpoises, *Phocoena phocoena*, in Funka Bay, Hokkaido, Japan. Marine Mammal Science 14:209–220.

Palka, D. 2011. NEFSC 1995 AJ9501 (Part I). Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/56) on 29 June 2016.

Palka, D. 2013*a*. NEFSC 1995 pe9501. Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/296) on 29 June 2016.

Palka, D. 2013*b*. NEFSC Mid-Atlantic Marine mammal Abundance Survey 2004. Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/396) on 29 June 2016.

Palka, D. 2013*c*. NEFSC Survey 1998 1. Data downloaded from OBIS-SEAMAP (http://seamap.env.duke.edu/dataset/60) on 29 June 2016.

Philpott, E., A. Englund, S. Ingram and E. Rogan. 2007. Using T-PODs to investigate the echolocation of coastal bottlenose dolphins. Journal of the Marine Biological Association of the United Kingdom 87:11–17.

Read, A. J., and A. J. Westgate. 1997. Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. Marine Biology 130:315–322.

Read, A. J., J. R. Nicolas and J. E. Craddock. 1995. Winter capture of a harbor porpoise in a pelagic drift net off North Carolina. Fishery Bulletin 94:381–383.

Read, A. J., S. Barco, J. Bell, *et al*. 2014. Occurrence, distribution and abundance of cetaceans in Onslow Bay, North Carolina, USA. Journal of Cetacean Research and Management 14:23–35.

Roch, M. A., H. Klinck, S. Baumann-Pickering, D. K. Mellinger, S. Qui, M. S. Soldevilla and J. A. Hildebrand. 2011. Classification of echolocation clicks from odontocetes in the Southern California Bight. Journal of the Acoustical Society of America 129:467–475.

Scott, M. D., A. A. Hohn, A. J. Westgate, J. R. Nicolas, B. R. Whitaker and W. B. Campbell. 2001. A note on the release and tracking of a rehabilitated pygmy sperm whale (*Kogia breviceps*). Journal of Cetacean Research and Management 3:87–94.

Stafford, K. M., D. K. Mellinger, S. E. Moore and C. G. Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999–2002. Journal of the Acoustical Society of America 122:3378–3390.

Verfuß, U. K., C. G. Honnel, A. Meding, M. Dähne, R. Mundry and H. Benke. 2007. Geographical and seasonal variation of harbour porpoise (*Phocoena phocoena*) presence in the German Baltic Sea revealed by passive acoustic monitoring. Journal of the Marine Biological Association of the United Kingdom 87:165–176.

Verfuß, U. K., L. A. Miller, P. K. D. Pilz and H. U. Schnitzler. 2009. Echolocation by two foraging harbour porpoises (*Phocoena phocoena*). Journal of Experimental Biology 212: 823–834.

Villadsgaard, A., M. Wahlberg and J. Tougaard. 2007. Echolocation signals of wild harbour porpoises, *Phocoena phocoena*. Journal of Experimental Biology 210:56–64.

Waring, G. T., E. Josephson, C. P. Fairfield-Walsh and K. Maze-Foley, eds. 2007. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments–2007. U. S. Department of Commerce, NOAA Technical Memorandum NMFS NE 205:100–113.

Westgate, A. J., A. J. Read, P. Berggren, H. N. Koopman and D. E. Gaskin. 1994. Diving behaviour of harbour porpoises, *Phocoena phocoena*. Canadian Journal of Fisheries and Aquatic Sciences 52:1064–1073.

Wiggins, S. M., and J. A. Hildebrand. 2007. High-frequency Acoustic Recording Package (HARP) for broad-band, long-term marine mammal monitoring. Pages 551–557 *in* International Symposium on Underwater Technology 2007 and International Workshop on Scientific Use of Submarine Cables & Related Technologies 2007. Institute of Electrical and Electronics Engineers, Tokyo, Japan.

Willis, P. M., and R. W. Baird. 1998. Status of the dwarf sperm whale, *Kogia simus*, with special reference to Canada. Canadian Field-Naturalist 112:114–125.

Würsig, B., S. K. Lynn, T. A. Jefferson and K. D. Mullin. 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. Aquatic Mammals 24:41–50.

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