Photo-Identification Analyses in the Cape Hatteras Study Area: 2022 Annual Progress Report

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Cover Photo Credit:

Adult male Cuvier's beaked whale (*Ziphius cavirostris*) surfacing off Cape Hatteras, North Carolina. Photographed by Andrew Read, Duke University, taken under General Authorization Letter of Confirmation 19903 held by Duke University.

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Acronyms and Abbreviations

AFTT	Atlantic Fleet Training and Testing
BRS	Behavioral Response Study
DTAG	Digital Acoustic Recording Tag
DUML	Duke University Marine Lab catalog
Gg	*Grampus griseus* (Risso's dolphin)
Gm	*Globicephala macrorhynchus* (short-finned pilot whale)
HAT	Cape Hatteras study area
HDR	HDR catalog
ID	identification
NOAA	National Oceanic and Atmospheric Administration
NOR	Norfolk Canyon study area
photo-ID	photo-identification
SLR	single-lens reflex
SP	Sutherland/Patteson catalog
Tt	*Tursiops truncatus* (bottlenose dolphin)
UNCW	University of North Carolina Wilmington catalog
Zc/Zca	*Ziphius cavirostris* (Cuvier's beaked whale)

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1. Cape Hatteras Photo-Identification

During fieldwork supporting the Atlantic Behavioral Response Study (BRS) in 2022 (Southall et al. 2023) and other related research, more than 15,000 digital images were collected within the Cape Hatteras study area. These images were used to confirm species, identify individual animals, and conduct follow-up monitoring of satellite-tagged animals. Digital photographs were taken with Canon or Nikon digital single lens reflex (or SLR) cameras equipped with 100- to 400-millimeter zoom lenses in 24-bit color at a resolution of 6016 × 4016 pixels and saved in .jpg format. Photographs were obtained from seven species, with most of them being Cuvier's beaked whales (*Ziphius cavirostris*), the primary focal species of BRS field efforts (**Table 1**).

Each digital image was graded for photographic quality and animal distinctiveness. All images of sufficient quality and distinctiveness were then sorted by individual within a sighting and assigned temporary identifications. The best image for each individual in that sighting was then selected, and these images were compiled into a folder for each sighting for later photo-identification (photo-ID); all of these images were cropped. Sighting data and photo-ID information were stored in an Access database managed by Kim Urian (Duke University Marine Lab).

Images of 110 newly identified animals were added to photo-ID catalogs of short-finned pilot whales (*Globicephala macrorhynchus*), Risso's dolphins (*Grampus griseus*), sperm whales (*Physeter macrocephalus)*, Atlantic spotted dolphins (*Stenella frontalis*), bottlenose dolphins (*Tursiops truncatus*) and Cuvier's beaked whales (**Table 2**). Additionally, 38 new photo-ID matches were made within the short-finned pilot whale and Cuvier's beaked whale catalogs. A bottlenose dolphin that was sighted twice in 2013 was also re-sighted in September 2021, nine years after its initial sighting; this is the longest resight for this species off Cape Hatteras (**Figure 1**). To date, photo-ID catalogs for 11 species have been assembled in the Cape Hatteras study area, across multiple U.S. Navy Atlantic Fleet Training and Testing (AFTT) monitoring projects, which include almost 2,200 distinct individuals, with 619 individuals re-sighted across all species (**Table 2**).

Table 1. Cetacean sightings with the number of photo-ID images collected for each species within the Cape Hatteras study area in 2022.

Species	Common Name	Number of Sightings	Number of Photo-ID Images
Globicephala macrorhynchus	Short-finned pilot whale	71	4,720
Grampus griseus	Risso's dolphin	2	189
Physeter macrocephalus	Sperm whale	1	25
Stenella clymene	Clymene dolphin	1	1
Stenella frontalis	Atlantic spotted dolphin	7	625
Tursiops truncatus	Bottlenose dolphin	60	772
Unidentified beaked whale	Unidentified beaked whale	2	2
Unidentified dolphin	Unidentified dolphin	4	3
Unidentified odontocete	Unidentified odontocete	2	13
Ziphius cavirostris	Cuvier's beaked whale	74	9,010
Total	--	**224**	**15,360**

Table 2. Summary of images collected during fieldwork within the Cape Hatteras study area in 2022, with number of new identifications (IDs), photo-ID catalog sizes, number of new re-sights, and total re-sights to date.

Species	New Images Collected	New IDs	Catalog Size	New Re-sights	Re-sights To Date
Balaenoptera physalus	0	0	1	0	0
Delphinus delphis	0	0	46	0	1
Globicephala macrorhynchus	4,720	36	1,375	7	476
Grampus griseus	189	6	47	0	6
Kogia sp.	0	0	1	0	0
Megaptera novaeangliae	0	0	2	0	0
Physeter macrocephalus	25	1	29	0	1
Stenella clymene	1	0	3	0	0
Stenella frontalis	625	9	42	0	0
Tursiops truncatus	772	9	369	0	18
Ziphius cavirostris	9,010	49	283	31	117
Total	**15,360**	**110**	**2,198**	**38**	**619**

Figure 1. Photographs of Ttr_9-013—initially sighted in March 2013 (top) and re-sighted in September 2021 (bottom).

1.1 Cuvier's Beaked Whales

Forty-nine new identifications were added to the *Ziphius* photo-ID catalog during 2022. An additional 31 whales were re-sighted, with re-sightings occurring both within and between years. The current re-sighting rate for *Ziphius* within the Cape Hatteras area is 41 percent, an increase from 2021, when it was 36 percent. To date, 81 of the 117 (69 percent) re-sighted *Ziphius* have been documented in multiple years, and 47 whales have been re-sighted more than three years after their initial sighting (**Tables 3 and 4;** tables and figures are provided at the end of this section). This is a notable increase over last year's photo-ID results, when only 28 whales had been sighted over more than a three-year period.

Eight *Ziphius* were tagged in 2022; two of these tagged individuals were matched to the photo-ID catalog. Zca_027r was first seen in December 2015; it was re-sighted in August 2018, in October 2020, and was finally satellite-tagged in June 2022 (ZcTag129); this animal is an adult male (**Figure 2**). Zca_065 was first seen in August 2018 without a calf and again in August 2019 with a moderately distinctive calf (Zca_148r). She was re-sighted in July 2021 with an apparently new calf (Zca_120); both had prominent scars that likely came from a shark. She and her second calf were re-sighted in June 2022, when she was satellite-tagged (ZcTag130; **Figure 3**).

We have observed individual *Ziphius* associating in the same groups over days to weeks, but long-term social associations continue to be rare. Previously, only two instances of a long-term association had been documented; the first was an adult male/adult female pair satellite-tagged in the same group in May 2016 (ZcTag046 and ZcTag047, respectively) and seen together again in June 2017. A second long-term association involved two adult males tagged in the same group of three in August 2018 (ZcTag071 and ZcTag072, respectively) and photographed together in a group of six in August 2020. Both whales were encountered again later that year, but in different groups. During this reporting period, we documented a third long term association. Zca_056 and Zca_035 were satellite-tagged in separate groups in August 2018 (ZcTag072 and ZcTag076, respectively) and were re-sighted together in August 2020 and August 2021; both are adult males.

The photographic histories of individual whales continue to be used to learn more about the demographics of *Ziphius* in the Cape Hatteras study area. We are particularly interested in estimating calving intervals of individual females and the survival of calves in the post-dependency period; a sufficient number of images of distinctive calves is beginning to make this analysis feasible (**Table 5**). For example, Zca_102 was seen with its mother (Zca_101) several times throughout the 2020 field season (**Figure 4**). Zca_120 was first photographed with its mother in July 2021; at the time, it was classified as a young-of-the year animal. As mentioned previously, the pair was re-sighted in June 2022 and the mother was satellite-tagged (ZcTag130; **Figure 5**); ZcTag130 had a prior calf that was also distinctive (Zca_148r). Additionally, Zca_067 was seen in August 2018 with a distinctive calf; she was re-sighted in June 2022 without the calf. If these distinctive calves can be resighted, this will be our first information about movements and associations of juvenile Cuvier's beaked whales at the Hatteras study site. We are hoping to continue to observe these distinctive calves to gain insight into the age at which calves separate from their mothers and to facilitate estimating calving intervals of adult females in this population.

Biopsy samples are continuing to be collected from off Cape Hatteras to assign sex to animals that lack erupted teeth or extensive scarring—the two characteristics used to identify adult males. Analysis of these samples will also provide important information on genetic relationships among individuals, effective population size, and biochemical markers of diet and stress. To date, we have collected 38 biopsy samples of *Ziphius*.

During this reporting period, Ali Pagliery, a Duke undergraduate student, examined the scarring density of individual animals of known genetic sex (assigned from molecular analysis of biopsy samples). She used photographs taken at the time of biopsy to quantify the percent of scarring in a defined region under the dorsal fin of each biopsied whale, following the methods developed by Coomber et al. (2022). She found that known females (n=9) had scarring densities ranging from 0 to 3.1 percent, while males (n=29) had scarring densities ranging from 0 to 34.7 percent (**Table 6**). Twenty of the 29 males had photographs of the head and face taken at the time of biopsy. These can be used to classify the animals as adult males if erupted teeth are present. All known subadult males (without erupted teeth) had scarring densities of 5 percent or less while all adult males, with the exception of one whale, had scarring densities of 5 percent or greater (**Table 7**). When the nine males without photographs of the head or face are included, it seems likely that most of those can be classified into an age class simply based on their scarring density (**Table 8**). These results will be used in the future to classify animals in our catalog that lack a head photograph but possess high scarring densities as adult males.

We are also interested in understanding the rate of scar acquisition in *Ziphius*. Victoria Carvajal, an undergraduate student at Arizona State University, used images of individual whales taken over time to examine scar acquisition in our population of *Ziphius*. She also used the method developed by Coomber et al. (2022) to quantify the percent of scarring in a defined region of interest under the dorsal fin. She used images of 11 whales in her analysis (1 adult female, 7 adult males and 3 whales of unknown sex). These images often varied in angle and orientation of the whale to the photographer, so she spent considerable time adapting and refining the protocol developed by Coomber at el. (2002) to account for this source of variation. She documented individual variation in rates of scar acquisition; however, in general, the greater the amount of scarring a whale possessed in its initial sighting, the higher its rate of subsequent scar acquisition. She hypothesized that animals that were already heavily scarred were perhaps more likely to engage in social behaviors that lead to more scarring. For example Zca_096r was first seen in August 2018 with minimal scarring on its body; it was re-sighted three years later in September 2021 with few, if any, additional scars (**Figure 6**). This contrasts with Zca_022, which was first photographed in June 2015; in its most recent photograph taken in October 2020 it had accumulated many new scars (**Figure 7**).

We have created three additional catalogs for *Ziphius* from images collected by other researchers and scientists, and are comparing our images of whales with these catalogs (**Table 9**). To date, we have made nine matches between the four catalogs; our three longest-term re-sightings are derived from these inter-catalog comparisons (**Table 10**). UNCW M-003 was first photographed by the aerial survey team off Cape Hatteras in August 2014. We then photographed the whale in 2015, 2019, 2020 and finally in June 2022, when it was seen for the first time with a calf, confirming that this individual is an adult female; this female acquired few if any new scars in eight years (**Figure 8**). SP M-003 was photographed by Kate Sutherland in May 2004 south of Cape Hatteras, and we tagged it 15 years

later in July 2019 (ZcTag090); this whale is an adult male. It is believed that this is the longest re-sighting record of a Cuvier's beaked whale in the Northwest Atlantic. SP M-004 was originally photographed by Kate Sutherland in July 2010, and was sighted off Cape Hatteras 10 years later in August 2020, when it was tagged (ZcTag108; **Figure 9**). Another inter-catalog match made during this reporting period was HDR M-001, which was first photographed in August 2020 at the Cape Hatteras study site and then photographed by HDR in August 2022 off Norfolk, Virginia (**Figure 10**). We have also documented occasional movements between Cape Hatteras and Norfolk Canyon from our large sample of satellite-tagged whales. These comparisons are increasing knowledge regarding the long-term and long-distance movements of this population (**Figure 11**).

Our sighting histories of individual whales will contribute to a meta-analysis of Cuvier's beaked whale demography funded by the Office of Naval Research and coordinated by Erin Falcone and Greg Schorr. The goal of this collaborative project is to compare vital rates of Cuvier's beaked whales across populations that experience varying exposure to military sonar. Pigmentation and scarring-density metrics will be applied to images from each population in a uniform manner, allowing us to classify individual whales according to age classes (calf, adult or juvenile) and, in some cases, sex. Estimation of vital rates for each population will require age- and sex-linked life-history data from a large sample of individual animals. It is important to have adequate samples of photo-ID data from each region; the Cape Hatteras photo-ID catalog is the largest in this dataset and will be an important contribution to this analysis.

Table 3. Sighting histories of Cuvier's beaked whales re-sighted over multiple years within the Cape Hatteras study area, 2004–2022.

Sighting ID[1]	Year											
	2004	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zca_001r			X		X							
Zca_002 (ZcTag074)			X					X[m]	X[m]			
Zc_003 (ZcTag124)				X				X			X[y]	
Zca_003r (ZcTag029)				X[m]				X				
Zca_005				X	X		X					
Zca_006 (ZcTag040)				X	X		X	X		X		
Zca_008r (ZcTag047)				X[y]		X[m]	X[y]	X[y]				
Zca_015 (ZcTag039, ZcTag077)					X			X				
Zca_016 (UNCW M-003)				X	X				X	X		X
Zca_019 (ZcTag043)				X	X							
Zca_020					X				X			
Zca_022					X					X		
Zca_023r					X				X[y]			
Zca_024 (ZcTag046, ZcTag103)						X	X			X[m]		
Zca_026						X					X[y]	
Zca_027r (ZcTag129)					X			X		X	X	X
Zca_028 (ZcTag051)						X					X[m]	
Zca_029 (ZcTag054)							X[y]				X[y]	
Zca_030 (ZcTag055)							X[y]		X[m]	X		
Zca_031 (ZcTag056)							X		X	X[y]	X[y]	
Zca_032							X	X[m]				
Zca_033							X			X		
Zca_034 (ZcTag126)							X				X[m]	
Zca_035 (ZcTag076)							X	X[y]			X	
Zca_035r (ZcTag048)						X		X				
Zca_036							X				X[y]	

Sighting ID[1]	Year											
	2004	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zca_037 (ZcTag068)							X[y]			X		
Zca_038							X	X			X	
Zca_040							X[y]		X			
Zca_043							X			X		
Zca_044r						X		X[m]		X		
Zca_046r						X				X		
Zca_048							X		X[m]			
Zca_049 (ZcTag114)								X			X[y]	
Zca_050 (ZcTag078)								X[y]			X	
Zca_050r (ZcTag057)							X	X				
Zca_051r (ZcTag058)							X[y]	X[m]				
Zca_052 (ZcTag084)								X	X[m]	X[m]		
Zca_054r (ZcTag049, ZcTag099)						X	X[y]		X	X[y]		
Zca_055 (ZcTag071)								X		X[m]		
Zca_056 (ZcTag072)								X		X[m]	X	
Zca_057 (ZcTag079)								X				X
Zca_058								X	X			
Zca_059								X[y]			X	
Zca_059r							X	X[y]				
Zca_061								X	X			
Zca_063 (ZcTag098)								X[m]		X[y]		
Zca_065								X	X		X	X
Zca_066								X[m]			X[m]	
Zca_067								X				X
Zca_067r (ZcTag060)							X			X	X	
Zca_068r							X				X	
Zca_071r (ZcTag081)							X	X[m]				
Zca_072									X		X	

Sighting ID[1]	Year											
	2004	**2010**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Zca_074									X		X	
Zca_074r							X	X			X[y]	
Zca_075									X	X[m]		
Zca_076									X[y]	X[y]		
Zca_077r (ZcTag085)								X	X[y]			
Zca_078 (ZcTag089, ZcTag109)									X	X		
Zca_082r								X	X			
Zca_083									X	X		X
Zca_086 (ZcTag091)									X[m]		X	
Zca_091 (ZcTag095)									X[m]	X		
Zca_092 (ZcTag096, ZcTag112)									X[m]		X	
Zca_096r								X[m]			X	
Zca_098 (ZcTag102, SP M-001)								X		X[m]	X[m]	
Zca_099										X	X[m]	
Zca_099r (ZcTag083)								X[m]	X			
Zca_106r (ZcTag111)								X		X[m]	X	
Zca_108r (ZcTag106)								X		X[y]	X	X
Zca_112r								X		X[y]	X	X
Zca_146r (ZcTag101)									X	X[m]	X	
Zca_162r (ZcTag104)										X[m]	X	
Zca_166r (ZcTag110)										X[m]	X	
UNCW M-002				X	X							
UNCW M-004			X				X					
SP M-002 (ZcTag127)								X			X	
SP M-003 (ZcTag090)	X								X			
SP M-004 (ZcTag108)		X								X[m]		
HDR M-001										X		X

[1] ID = Identification; Zca=*Ziphius cavirostris* (Cuvier's beaked whale); UNCW M=aerial-vessel match to University of North Carolina Wilmington catalog; SP M= matches made to the Sutherland/Patteson catalog from seabirding trips south of Cape Point; HDR M= matches made to the HDR catalog from vessel research trips offshore Norfolk, Virginia.

r – Cuvier's beaked whales that are identified by scarring patterns (rake marks)

m – Re-sighted within same month

y – Re-sighted within same year

Table 4. Frequency distribution of the number of years between first and last sightings of photo-ID Cuvier's beaked whales in the Cape Hatteras study area.

Number of Years Between First and Last Sighting	Number of Individuals
Less than 1	39
1 to 2	20
2 to 3	11
3 to 4	20
4 to 5	17
5 to 6	4
6 to 7	2
7 to 8	2
More than 8	2
Total	**117**

Table 5. Identifications and sighting histories of distinctive Cuvier's beaked whale calves.

Calf ID	Sighting Date(s)
Zca_068	August 2018
Zca_141r	July 2019
Zca_148r	August 2019
Zca_183r	August 2020
Zca_102	August 2020, October 2020
Zca_120	July 2021, June 2022, August 2022

Notes: ID = identification; Zca = *Ziphius cavirostris* (Cuvier's beaked whale)

Table 6. Identification codes, percent scarring within the defined region of interest, and genetic sex of biopsied Cuvier's beaked whales.

Biopsy ID	% Scarring	Genetic Sex
HJF_20_007	0.0	Female
ZTS_15_015	0.0	Male
ZTS_18_012	0.0	Male
ZTS_21_016	0.0	Female
ZTS_15_017	0.1	Female
HJF_21_006	0.3	Male
ZTS_13_031	0.3	Female
ZTS_21_019	0.6	Female
HJF_21_004	0.6	Male
HJF_21_007	0.6	Male
HJF_21_010	0.8	Female
ZTS_21_020	1.0	Male
ZTS_21_014	1.1	Male
AJR_18_001	1.4	Female
HJF_21_011	1.4	Male
ZTS_21_021	1.5	Female
HJF_21_003	1.6	Male
HJF_21_005	2.0	Male
HJF_21_009	2.5	Male
HJF_18_004	3.1	Female
HJF_20_010	4.0	Male
ZTS_21_015	4.1	Male
HJF_20_009	4.6	Male
ZTS_21_018	4.9	Male
WRC_21_002	5.0	Male
HJF_20_005	5.1	Male
ZTS_18_011	6.1	Male
HJF_21_008	7.2	Male

Biopsy ID	% Scarring	Genetic Sex
WRC_21_003	10.5	Male
HJF_21_002	10.6	Male
HJF_20_006	14.4	Male
WRC_21_004	16.9	Male
ZTS_21_017	19.5	Male
HJF_18_002	19.6	Male
ZTS_13_032	21.0	Male
HJF_18_003	22.2	Male
ZTS_17_004	33.6	Male
HJF_18_001	34.7	Male

Note: ID = identification.

Table 7. Identification codes, percent scarring within the defined region of interest, and genetic sex and age class determined by the presence/absence of erupted teeth of biopsied Cuvier's beaked whales.

Biopsy ID	% Scarring	Sex/Age Class
HJF_21_006	0.3	Subadult Male
ZTS_21_014	1.1	Subadult Male
HJF_21_011	1.4	Subadult Male
HJF_21_005	2.0	Subadult Male
HJF_21_009	2.5	Subadult Male
HJF_20_010	4.0	Subadult Male
ZTS_21_015	4.1	Subadult Male
HJF_20_009	4.6	Adult Male
WRC_21_002	5.0	Subadult Male
HJF_20_005	5.1	Adult Male
HJF_21_008	7.2	Adult Male
WRC_21_003	10.5	Adult Male
HJF_21_002	10.6	Adult Male
HJF_20_006	14.4	Adult Male
WRC_21_004	16.9	Adult Male
ZTS_21_017	19.5	Adult Male
HJF_18_002	19.6	Adult Male
ZTS_13_032	21.0	Adult Male
HJF_18_003	22.2	Adult Male
ZTS_17_004	33.6	Adult Male

Note: ID = identification

Table 8. Identification codes, percent scarring within the defined region of interest, and genetic sex and age class of biopsied Cuvier's beaked whales; whales with no head photograph to show presence or absence of teeth are shown in red.

Biopsy ID	% Scarring	Sex/Age Class
ZTS_15_015	0.0	Male
ZTS_18_012	0.0	Male
HJF_21_006	0.3	Subadult Male
HJF_21_004	0.6	Male
HJF_21_007	0.6	Male
ZTS_21_020	1.0	Male
ZTS_21_014	1.1	Subadult Male
HJF_21_011	1.4	Subadult Male
HJF_21_003	1.6	Male
HJF_21_005	2.0	Subadult Male
HJF_21_009	2.5	Subadult Male
HJF_20_010	4.0	Subadult Male
ZTS_21_015	4.1	Subadult Male
HJF_20_009	4.6	Adult Male
ZTS_21_018	4.9	Male
WRC_21_002	5.0	Subadult Male
HJF_20_005	5.1	Adult Male
ZTS_18_011	6.1	Male
HJF_21_008	7.2	Adult Male
WRC_21_003	10.5	Adult Male
HJF_21_002	10.6	Adult Male
HJF_20_006	14.4	Adult Male
WRC_21_004	16.9	Adult Male
ZTS_21_017	19.5	Adult Male
HJF_18_002	19.6	Adult Male
ZTS_13_032	21.0	Adult Male
HJF_18_003	22.2	Adult Male
ZTS_17_004	33.6	Adult Male
HJF_18_001	34.7	Male

Note: ID = identification

Table 9. Number of images in each Cuvier's beaked whale catalog and years when the images were collected.

Catalog Descriptor[a]	Catalog Location	Years Images Collected	Number of Individuals
UNCW	Cape Hatteras, North Carolina Aerial Surveys	2012–2017	51
SP	South of Cape Point, North Carolina	2003–2018	25
HDR	Norfolk, Virginia	2019–2022	3
DUML	Cape Hatteras, North Carolina	2007–2022	283

[a] UNCW= University of North Carolina Wilmington catalog made from aerial surveys; SP= Sutherland/Patteson catalog from seabirding trips south of Cape Point; HDR= HDR catalog from research trips offshore Norfolk, Virginia; DUML= Duke University Marine Lab catalog from research trips off Cape Hatteras

Table 10. Summary of photo-ID matches made between the Duke University catalog and external Cuvier's beaked whale catalogs.

Match Number	Initial Sighting	Last Sighting	Years Between Initial and Last Sightings
UNCW M-001	August 2014	September 2014	0.1
UNCW M-002	September 2014	May 2015	0.7
UNCW M-003	August 2014	June 2022	7.8
UNCW M-004	May 2013	August 2017	4.2
SP M-001	May 2018	August 2020	2.2
SP M-002	May 2018	September 2021	3.3
SP M-003	May 2004	August 2019	15.2
SP M-004	July 2010	August 2020	10.1
HDR M-001	August 2020	August 2022	2.0

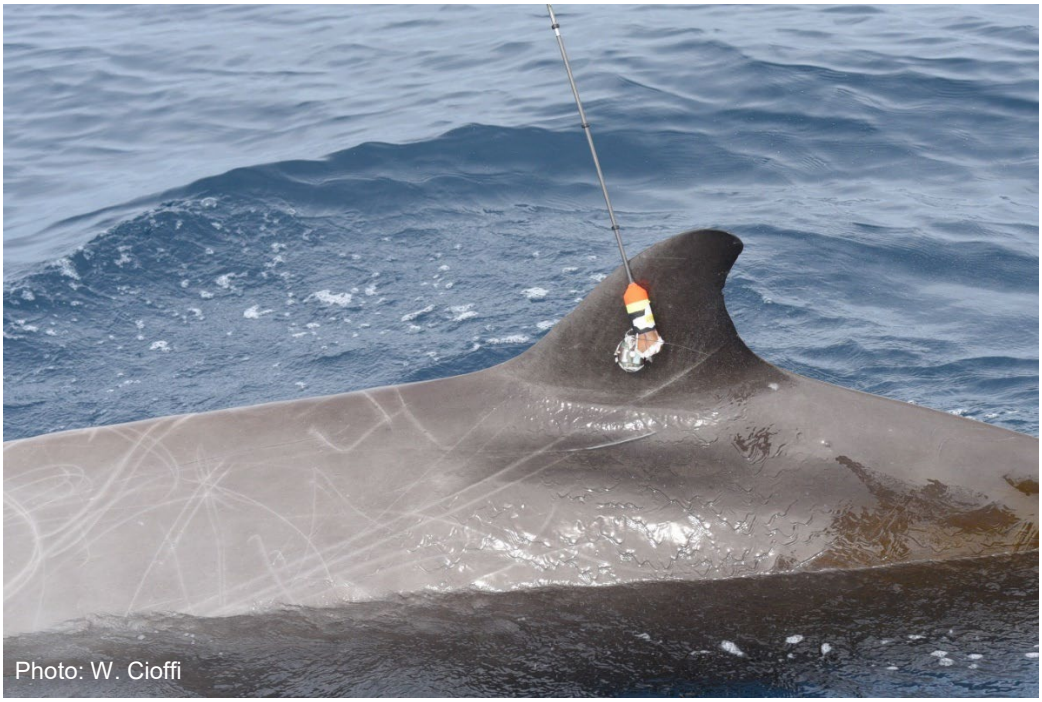

Figure 2. Photographs of Zca_027r, initially sighted in 2015, resighted in 2018 (top) and 2020 and satellite-tagged in 2022 (ZcTag129; bottom).

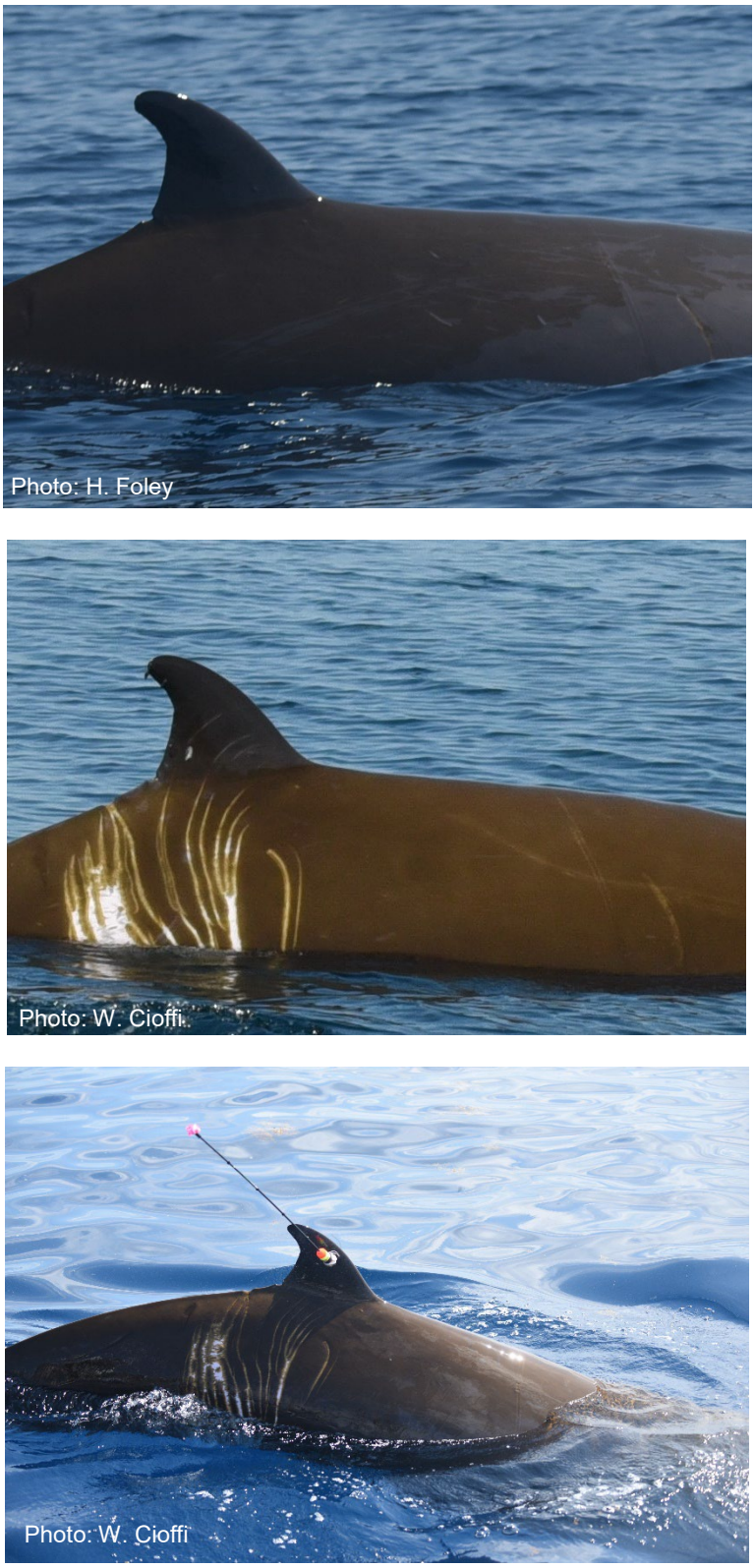

Figure 3. Photographs Zca_065, initially sighted in 2018 (top) re-sighted in 2019 and 2021 (middle) and satellite-tagged in 2022 (ZcTag130; bottom).

Figure 4. Photograph of Zca_102, the calf of Zca_101, in August 2020.

Figure 5. Photograph of Zca_120, the calf of Zca_065 (ZcTag130), in July 2021.

Figure 6. Photographs of Zca_096r, initially sighted in August 2018 (top) and re-sighted in September 2021 (bottom). Note that few, if any, new scars have been accumulated over that period.

Figure 7. Photographs of Zca_022, initially sighted in June 2015 (top) and re-sighted in October 2020. Note the heavy accumulation of new scars during that period.

Figure 8. Photographs of UNCW M-003, initially sighted in 2014 and re-sighted in 2015 (top), 2019, 2020, and 2022 (bottom).

Figure 9. Photographs of SP M-004, initially sighted in July 2010 (top) and re-sighted and satellite-tagged in August 2020 (bottom).

Figure 10. Photographs of HDR M-001, initially sighted in August 2020 (top) and re-sighted in August 2022 (bottom).

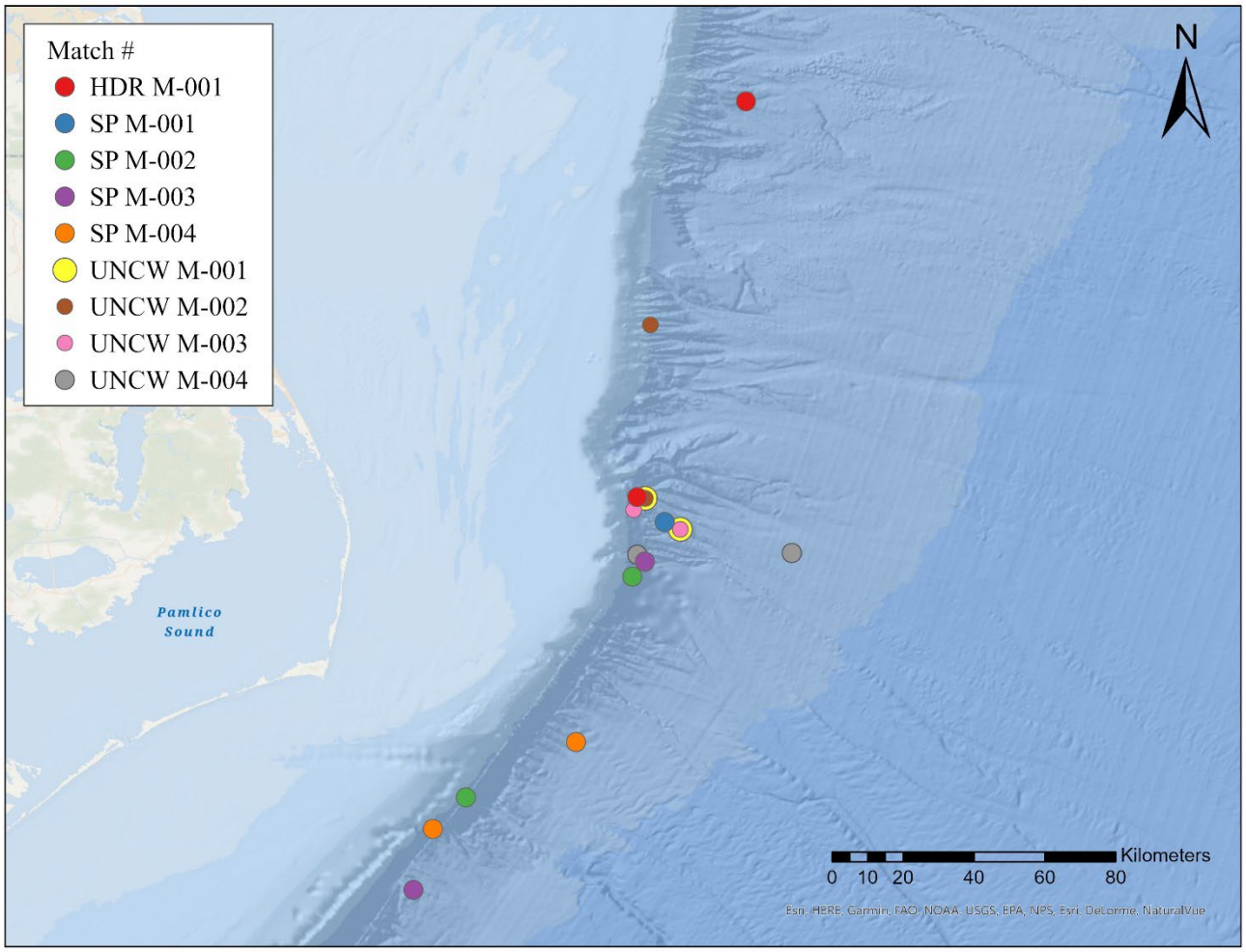

Figure 11. Map of sighting locations of Cuvier's beaked whales matched between the Duke University catalog and three external catalogs (HDR = HDR catalog from Norfolk, Virginia; SP = Sutherland/Patteson catalog from south of Cape Point; UNCW = University of North Carolina Wilmington catalog from aerial surveys).

1.2 Short-Finned Pilot Whales

Despite relatively little field effort directed at this species, we added 36 new identifications and seven new re-sightings to the short-finned pilot whale catalog in 2022. The current re-sighting rate of this species is 35 percent, comparable to the rate documented in 2021. More than 200 short-finned pilot whales have been seen on three or more occasions, and 14 animals have been re-sighted more than six times (**Table 11;** tables and figures are provided at the end of this section). More than 100 short-finned pilot whales have been biopsied in the study area between 2006 and 2022 and the sex of 95 whales has been determined from molecular analysis of these samples, with 69 males and 26 females sampled to date.

Short-finned pilot whales return to or are resident in the Cape Hatteras study area over extended periods. Almost 120 pilot whales have spans of at least five years between their first and last sightings, and 23 pilot whales have records that span a decade or more (**Table 12**). Three of these 23 whales were satellite-tagged and three others were biopsied (one male, two females). These long-term photo-ID records demonstrate that both male and female short-finned pilot whales exhibit strong, but possibly intermittent, site fidelity to the Cape Hatteras area. Additionally, a new long-term re-sighting was found during this period: Gma_1-065 was first seen in May 2008; it was re-sighted in July 2010 and again in October 2022, when it was accompanied by a calf (**Figure 12**). This 14-year period represents the longest re-sighting of a short-finned pilot whale off Cape Hatteras.

Four short-finned pilot whales off Cape Hatteras were equipped with Digital Acoustic Recording Tags (DTAGs) in 2022; one was matched to our photo-ID catalog. Gma_8-072 was first photographed in October 2015 and was tagged in October 2022 (**Figure 13**). No pilot whales were satellite-tagged during the 2022 field season.

We have documented many associations of short-finned pilot whales over relatively long periods. For example, Gma_8-075 and Gma_9-094 were first photographed in the same group in May 2007 and were later seen together in December 2015. Four pilot whales (Gma_1-023, Gma_1-030, Gma_7-016, and Gma_7-112) were observed together in May of 2008 and again in May 2015. Another two pilot whales (Gma_9-010 and Gma_9-118) were photographed in the same group four times between 2007 and 2014. During this reporting period we made another long-term association. Five pilot whales (Gma_1-099, Gma_6-331, Gma_7-430, Gma_8-191 and Gma_9-168) were seen in the same group in August 2017 and re-sighted together four years later in August 2021. These long-term associations confirm the social bonds in this strongly matrifocal species.

The 36 newly identified short-finned pilot whales added to the Cape Hatteras photo-ID catalog were systematically compared to catalogs for this species from Onslow Bay, North Carolina and Jacksonville, Florida, but no new matches were made between the study areas. We have previously matched four pilot whales between the Cape Hatteras and Onslow Bay study areas. Gma_8-165 was seen in Onslow Bay, in a group of 40 short-finned pilot whales in August 2007 and re-sighted and satellite-tagged (GmTag209) in the Cape Hatteras area 11 years later in August 2018. Three other short-finned pilot whales were also photographed with Gma_8-165 in both of these sightings. These four photo-ID matches are the only short-finned pilot whale matches documented between the Cape

Hatteras and Onslow Bay catalogs. To date, we have not made any matches between the Cape Hatteras and Jacksonville catalogs.

Jessica Aschettino provided images of short-finned pilot whales collected by HDR researchers during their field work in Norfolk Canyon in 2021 and 2022 (**Table 13**). We graded approximately 1,100 images for photographic quality and animal distinctiveness and all images of sufficient quality and distinctiveness were then sorted by individual within each sighting. The best image for each individual was then compared to the existing Norfolk photo-ID catalog. We added a total of 15 new individuals to the Norfolk short-finned pilot whale catalog (**Table 14**). There were no new re-sightings within the Norfolk pilot whale catalog; as reported last year, 10 short-finned pilot whales were re-sighted by HDR researchers during their field work from 2015 through 2022 (**Table 15**). We compared short-finned pilot whales in the Norfolk catalog to the Hatteras short-finned pilot whale catalog, which contains 1,375 individuals. One new match was made between the two areas, adding to the 43 previous matches; M-047 was seen off Cape Hatteras, North Carolina in May 2015 and was re-sighted seven years later off Norfolk, Virginia (**Table 16**). Therefore, 15 percent (44 of 295) of pilot whales observed in the Norfolk Canyon have also been photographed within the Cape Hatteras area. Comparing the two catalogs provides additional long-term re-sighting information; 13 of the pilot whales were seen within Cape Hatteras from 2007 to 2009, but not observed again until they were photographed in the Norfolk Canyon area from 2015 onwards. We also compared the new Norfolk pilot whale IDs to our short-finned pilot whale catalogs from Onslow Bay, North Carolina and Jacksonville, Florida but did not make any matches.

We are still in the process of comparing two catalogs of short-finned pilot whale photos collected from researchers and volunteers working around Martinique and Guadeloupe Islands in the Caribbean contributed by Dr. Jeremy Kiszka of Florida International University. We compared both Caribbean catalogs to our short-finned pilot whale catalogs from Jacksonville, Florida; Onslow Bay; and Cape Hatteras, North Carolina; there were several potential matches between the sites, but they could not be confirmed due to poor photographic quality (**Table 17**).

We have also finished comparing both of the Caribbean catalogs to a catalog of short-finned pilot whales that we created from images taken during research cruises conducted by National Oceanic and Atmospheric Administration (NOAA) scientists in the Gulf of Mexico and contributed by Keith Mullin of the Southeast Fisheries Science Center. Several potential matches were made and images were circulated to Dr. Jeremy Kiszka, Andrew Read (Duke University) and Kim Urian; however, all agreed that the matches could not be confirmed either due to poor photographic quality or minimal animal distinctiveness. In the coming year, we plan to finish comparisons between the Caribbean catalogs and the catalog of short-finned pilot whales off Norfolk, Virginia, and hope to receive further image contributions from Dr. Kiszka from the Caribbean, including whales harvested for human consumption within St. Vincent.

Linkages between pilot whales within the Caribbean and those inside the U.S. Exclusive Economic Zone are important, because short-finned pilot whales are still harvested within St. Vincent and elsewhere within the Caribbean. Sophie Hanson, an undergraduate at Duke University, completed an Honor's thesis looking at the genomics of short-finned pilot whales using biopsy samples collected from the Caribbean nation of St. Vincent and the Grenadines (n=17), Jacksonville, Florida (n=7); and

Hatteras, North Carolina (n=36). She used single nucleotide polymorphisms to infer genetic differentiation or similarity. Her results support the hypothesis that there is genetic population connectivity between short-finned pilot whales in St. Vincent, Florida and North Carolina (Hanson 2022).

Table 11. Frequency distribution of the number of sightings of photo-ID short-finned pilot whales within the Cape Hatteras study area.

Number of Sightings	Number of Individuals
1	899
2	272
3	97
4	60
5	25
6	8
7	8
8	4
9	1
10	0
11	1
Total	**1,375**

Table 12. Frequency distribution of the number of years between first and last sightings of photo-ID short-finned pilot whales within the Cape Hatteras study area.

Number of Years Between First and Last Sighting	Number of Individuals
Less than 1	132
1 to 2	49
2 to 3	45
3 to 4	63
4 to 5	69
5 to 6	17
6 to 7	20
7 to 8	43
8 to 9	14
9 to 10	1
10 to 11	13
11 to 12	7
More than 12	3
Total	**476**

Table 13. Number of sightings of short-finned pilot whales and number of images collected by year within the Norfolk Canyon area.

Year	Number of Sightings	Number of Photo-ID Images
2021	2	198
2022	9	882
Total	**11**	**1,080**

Table 14. Catalog sizes for short-finned pilot whales within the Norfolk Canyon area, including the original 2015–2019 catalog and individuals added during recent photo-ID efforts.

Species	2015–2020 Catalog	2021–2022 New IDs	Current Catalog Size	New Re-sights	Total Re-sights
Globicephala macrorhynchus	280	15	295	0	10

Note: ID = identification

Table 15. Photo-ID re-sighting histories of short-finned pilot whales off Norfolk, Virginia.

Sighting ID	Year							
	2015	2016	2017	2018	2019	2020	2021	2022
Gma_1-008		X	X					
Gma_6-010	X	X						
Gma_7-013	X	X						
Gma_7-016	X					X		
Gma_7-017	X					X		
Gma_7-020	X				X			
Gma_7-039	X	X						
Gma_7-041		X	X					
Gma_7-054		X	X					
Gma_9-022		X					X	

Table 16. Photo-ID matches by year of individual short-finned pilot whales, 2007–2022, between the Cape Hatteras and Norfolk Canyon study areas.

Match ID	Year															
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
M-001 (GmTag089)								HAT	NOR							
M-002								HAT	NOR							
M-003								HAT	NOR							
M-004		HAT							NOR							
M-005		HAT							NOR							
M-006	HAT	HAT[m]							NOR							
M-007 (GmTag091)								HAT	NOR							
M-008								HAT	NOR							
M-009	HAT								NOR							
M-010							HAT		NOR							
M-012 (GmTag177)										NOR	HAT					
M-013									HAT	NOR						
M-014									HAT	NOR						
M-015									HAT	NOR	HAT					
M-016									HAT	NOR	HAT					
M-017						HAT				NOR						
M-018	HAT								NOR							
M-019									HAT	NOR						
M-020								HAT		NOR						
M-021	HAT[m]		HAT							NOR						
M-023									HAT	NOR						
M-024									HAT	NOR						
M-025 (GmTag223)	HAT[y]		HAT							NOR			HAT[m]			
M-026							HAT			NOR					NOR	
M-028									HAT		NOR					
M-029									HAT		NOR					
M-030									HAT		NOR					

Match ID	Year															
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
M-031							HAT				NOR					
M-032						HAT							NOR			
M-033	HAT												NOR			
M-034 (GmTag158)										HAT	NOR					
M-035									HAT		NOR					
M-036		HAT			HAT						NOR					
M-037		HAT									NOR					
M-038	HAT	HAT									NOR					
M-039	HAT	HAT									NOR					
M-040		HAT						HAT	HAT[m]		NOR					
M-041 (GmTag096)		HAT		HAT		HAT[y]		HAT			NOR	HAT[y]				
M-042	HAT[m]												NOR			
M-043				HAT		HAT[m]	HAT				NOR					
M-044												HAT		NOR		
M-045												HAT		NOR		
M-046							HAT								NOR	
M-047									HAT							NOR

Notes: HAT = Cape Hatteras study area; NOR = Norfolk Canyon study area

m – Re-sighted within same month

y – Re-sighted within same year

Table 17. Number of images in each short-finned pilot catalog, years when the images were collected, and whether the catalogs have been compared to the Caribbean catalogs.

Catalog Location	Years Images Collected	Number of Individuals	Comparisons to the Caribbean Catalogs Completed
Guadeloupe, Caribbean	2010–2020	210	N/A
Martinique, Caribbean	2013–2016	130	N/A
Jacksonville, Florida	2009–2018	52	Yes
Onslow Bay, North Carolina	2007–2013	24	Yes
Gulf of Mexico	2003–2007	180	Yes
Hatteras, North Carolina	2006–2022	1,375	Yes
Norfolk, Virginia	2015–2022	295	Ongoing

Figure 12. Photographs of Gma_1-065 in May 2008 (top), July 2010 (middle), and October 2022 (bottom).

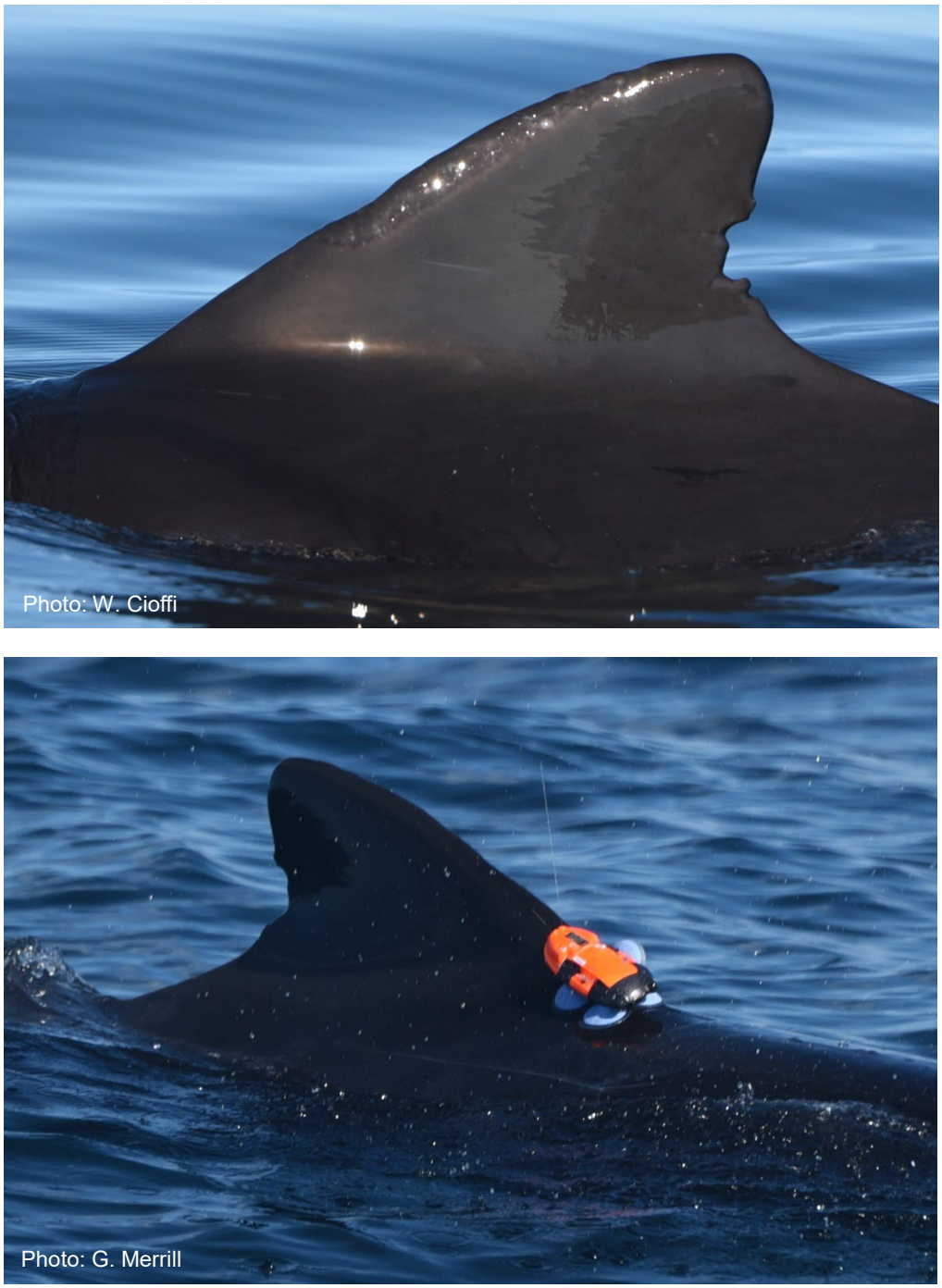

Figure 13. Photographs of Gma_8-072 in October 2015 (top) and October 2022, when it was equipped with a DTAG (bottom).

1.3 Satellite Tag Post-Deployment Monitoring

Follow-up monitoring of the health of satellite-tagged animals continues to be an important focus of our photo-ID efforts. We have deployed 96 satellite tags on 91 individual Cuvier's beaked whales between 2014 and 2022 and re-sighted 64 of these animals (70 percent). Many re-sightings occurred within the same field season, but 32 of the re-sighted whales (50 percent) were photographed at least one year after tagging (**Table 18**).

ZcTag106 was satellite-tagged in August 2020. It was re-sighted several times during that field season and was seen again in July 2021 and October 2022. Photographs show that the tag was shed by 2021, leaving well-healed scars that diminished over the year, based on photographs from 2022 (**Figure 14**). ZcTag115 was satellite-tagged in July 2021; it was re-sighted several months later in September 2021 and the tag had already been shed, leaving several small scars (**Figure 15**). This is our first documentation of a functioning satellite tag being shed within the deployment field season.

In 2022 four Cuvier's beaked whales were re-sighted for the first time since they were satellite-tagged (**Table 18**). As we have documented in previous years (Waples and Read 2022), the *Ziphius* in our population showed various effects of satellite-tagging. ZcTag079 was satellite-tagged in 2018 and not re-sighted until August 2022; the photographs are of marginal quality, but it appears that a single piece of hardware remains in the dorsal fin. ZcTag114 and ZcTag122 were tagged in July and August 2021, respectively, and were re-sighted in June and August 2022, respectively; both whales had shed their tags and all hardware, and had only well-healed scars remaining (**Figure 16**). ZcTag121 was tagged in July 2021 and was re-sighted several more times during the 2021 field season, then re-sighted in June 2022; the satellite tag was still in the dorsal fin although the tag was no longer transmitting (**Figure 17**).

To date, we have deployed 80 satellite tags on 79 short-finned pilot whales off Cape Hatteras and resighted 31 of these animals (39 percent). Most of these re-sightings occurred within the same field season, but 12 of the re-sights (39 percent) occurred across multiple years (**Table 18**). We had several re-sightings of satellite-tagged short-finned pilot whales during the 2022 field season. GmTag134 and GmTag135 were tagged in the same group in October 2015 along with four other pilot whales. All six whales were seen together in June 2018, and all were photographed in the same group seven years after their initial sighting, in October 2022. GmTag201 was tagged in May 2018 and re-sighted once in June 2018 but not seen again until it was photographed in August 2022. The tag and all hardware had been shed leaving only two well-healed scars at the tag location (**Figure 18**).

Table 18. Photo-ID sighting histories of cetaceans satellite-tagged and re-sighted within the Cape Hatteras study area; note a red X denotes the year when satellite tagging occurred for that individual.

Tag ID[a]	Year									
	2006-2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
GgTag017				X[m]						
GmTag087		X[y]								
GmTag089		X	X							
GmTag091	X	X	X							
GmTag096	X[y]	X			X	X[y]				
GmTag097	X[y]	X	X							
GmTag122	X		X[m]							
GmTag127			X[m]							
GmTag134			X			X				X
GmTag135			X[y]			X	X			X
GmTag136	X		X[y]			X[m]				
GmTag140			X		X					
GmTag157				X	X					
GmTag172					X[m]					
GmTag175	X				X[m]					
GmTag176	X		X					X		
GmTag179					X	X				
GmTag182					X[m]					
GmTag197	X	X	X		X	X[y]				
GmTag198 (GmTag227)	X					X[y]	X[y]			
GmTag199						X[m]				
GmTag201						X[y]				X
GmTag203						X[y]				
GmTag204			X[y]			X[y]				
GmTag205						X[y]				
GmTag206						X[y]				
GmTag207	X[y]		X			X[m]				
GmTag208						X[m]				
GmTag216						X[m]				
GmTag218	X[y]		X[m]			X[m]				
GmTag223	X[y]			X			X[m]			
GmTag226							X[y]			

Tag ID[a]	Year									
	2006-2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TtTag015		X[m]								
ZcTag029		X[m]				X				
ZcTag039 (ZcTag077)			X			X				
ZcTag040		X	X		X	X		X		
ZcTag046 (ZcTag103)				X	X			X[m]		
ZcTag047		X[y]		X[y]	X[y]	X[y]				
ZcTag048				X		X				
ZcTag049 (ZcTag099)				X	X[y]		X	X		
ZcTag051				X					X[m]	
ZcTag054					X[y]				X	
ZcTag055					X[y]		X[m]	X		
ZcTag056					X		X	X[y]	X[y]	
ZcTag057					X	X				
ZcTag058					X[y]	X[m]				
ZcTag060					X[y]			X	X	
ZcTag062					X[m]					
ZcTag069						X[y]				
ZcTag071						X		X[m]		
ZcTag072						X		X[m]		
ZcTag073						X[y]				
ZcTag074	X					X[m]	X[m]			
ZcTag075						X[m]				
ZcTag076					X	X[m]		X[m]	X	
ZcTag078						X[m]			X	
ZcTag079						X				X
ZcTag080						X[m]				
ZcTag081					X	X[m]				
ZcTag082							X[y]			
ZcTag084						X	X[m]	X[m]		
ZcTag085						X	X[y]			
ZcTag086							X[y]	X[y]		
ZcTag088							X[m]			
ZcTag089 (ZcTag109)							X[m]	X		

Tag ID[a]	Year									
	2006-2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
ZcTag090							X[y]			
ZcTag091							X[m]			
ZcTag092							X[y]			
ZcTag093							X[y]			
ZcTag095							X[m]	X		
ZcTag096 (ZcTag112)							X[m]		X	
ZcTag097							X[m]			
ZcTag098						X[m]		X[y]		
ZcTag101							X	X[m]	X	
ZcTag102								X[m]	X[m]	
ZcTag104								X[m]	X	
ZcTag105								X[m]		
ZcTag106						X		X[y]	X	X
ZcTag107								X[y]		
ZcTag108								X[m]		
ZcTag110								X[m]	X	
ZcTag111						X		X[m]	X	
ZcTag114						X			X[y]	X
ZcTag115									X[y]	
ZcTag116									X[y]	
ZcTag117									X[y]	
ZcTag120									X[y]	
ZcTag121									X[y]	X
ZcTag122									X[y]	X
ZcTag123									X[y]	
ZcTag124		X				X			X[y]	
ZcTag125									X[m]	
ZcTag126					X				X[m]	
ZcTag129			X			X		X		X[y]
ZcTag130						X	X		X	X[y]
ZcTag131										X[m]
ZcTag135										X[m]

[a] ID = identification; Gg= *Grampus griseus* (Risso's dolphin); Gm= *Globicephala macrorhynchus* (short-finned pilot whale); Tt=*Tursiops truncatus* (bottlenose dolphin); Zc=*Ziphius cavirostris* (Cuvier's beaked whale)

m – Re-sighted within same month
y – Re-sighted within same year

Figure 14. Photographs of ZcTag106 during satellite-tagging in August 2020 (top), at re-sight in July 2021 (middle), and during a second re-sight in October 2022 (bottom).

Figure 15. Photographs of ZcTag115 during satellite-tagging in July 2021 (top) and at re-sight in September 2021 (middle and bottom).

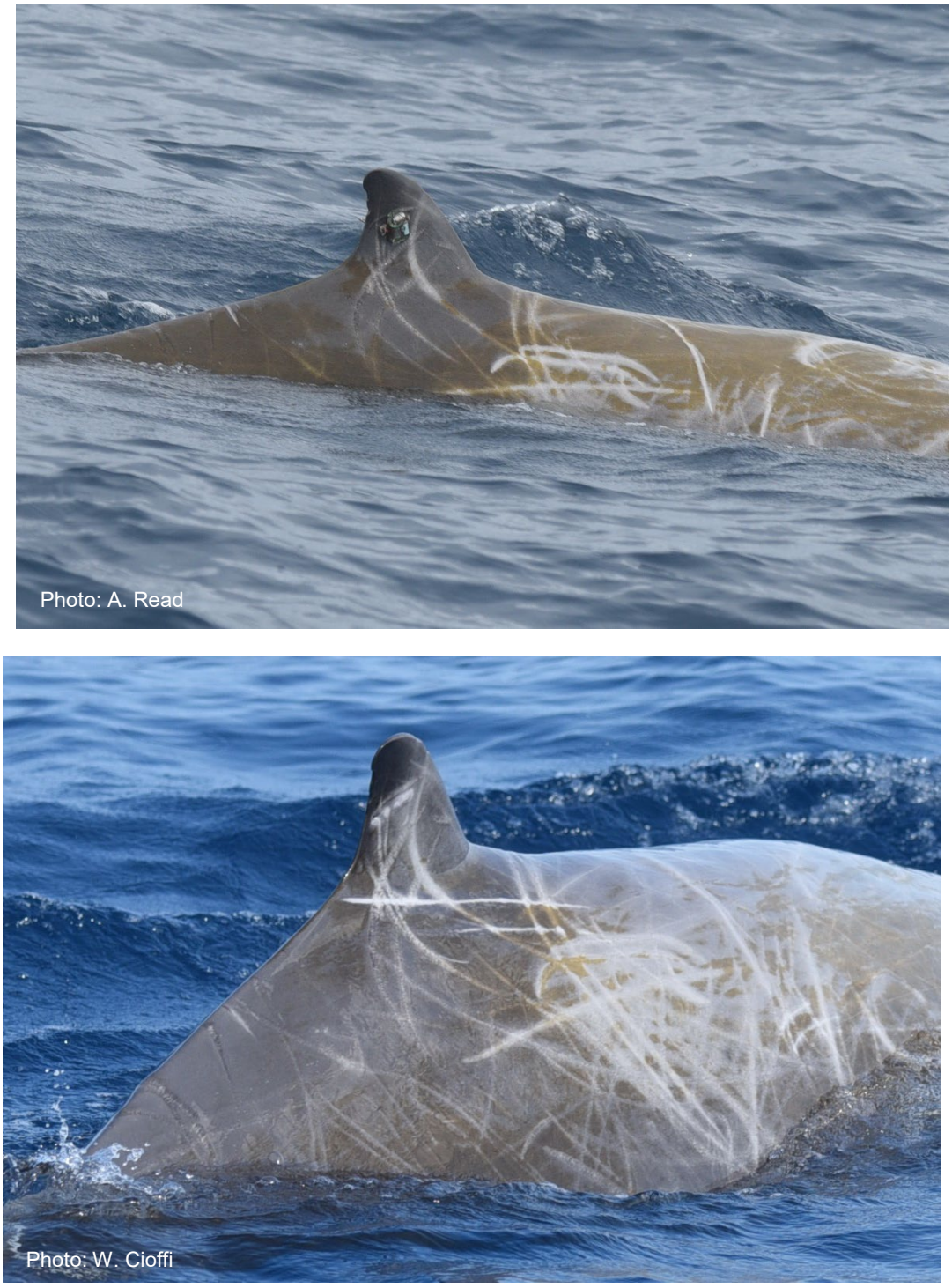

Figure 16. Photographs of ZcTag114 during satellite-tagging in July 2021 (top) and re-sight in June 2022 (bottom).

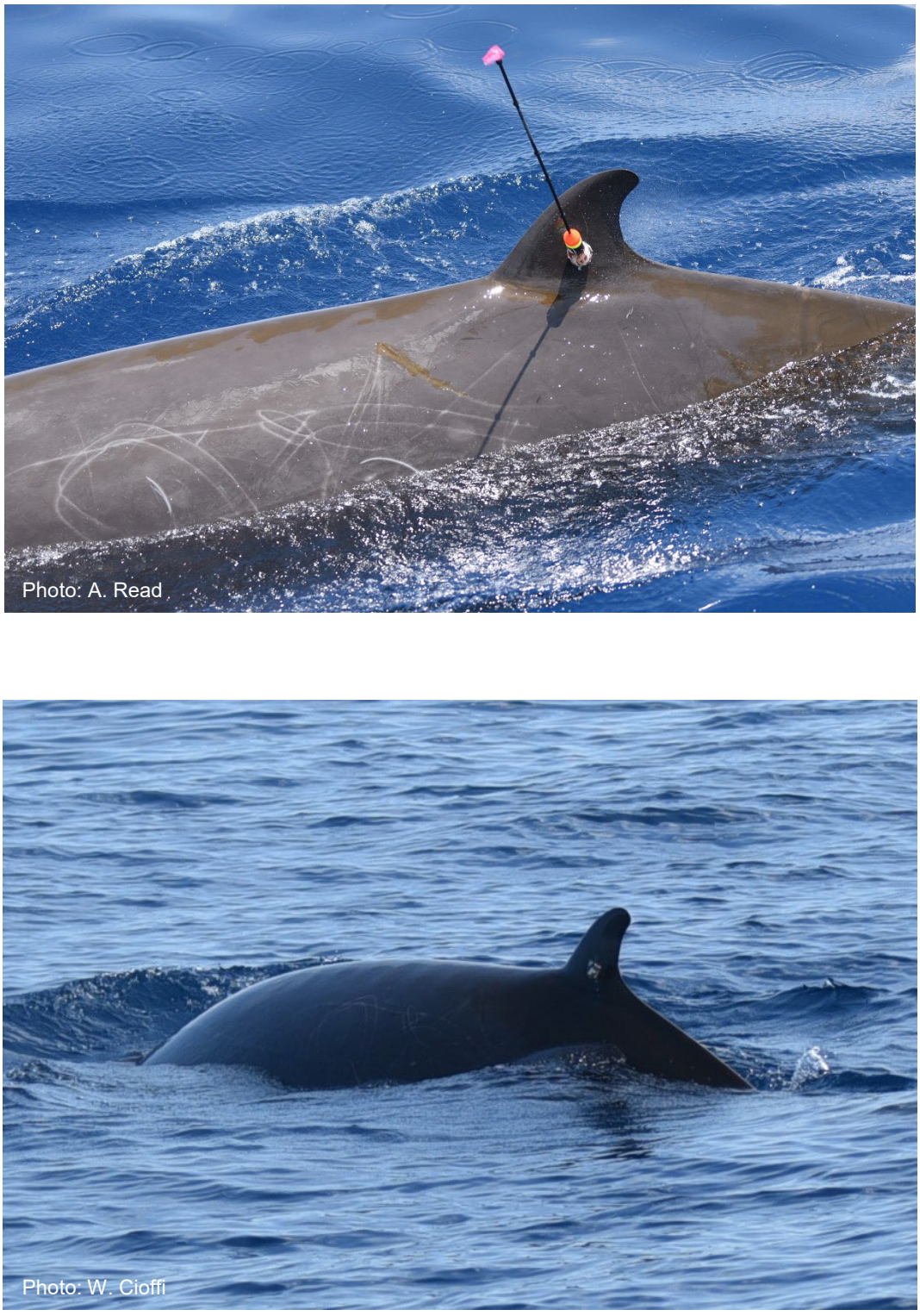

Figure 17. Photographs of ZcTag121 during satellite-tagging in July 2021 (top) and re-sight in June 2022 (bottom).

Figure 18. Photographs of GmTag201 during satellite-tagging in May 2018 (top) and re-sight in August 2022 (bottom).

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