Photo-Identification Analyses in the Cape Hatteras Study Area: 2020 Annual Progress Report

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Cover Photo Credit:

Cuvier's beaked whale (*Ziphius cavirostris*) and Research Vessel Shearwater. Photographed by Heather Foley, Duke University, taken under General Authorization Letter of Confirmation 19903 held by Duke University.

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Acronyms and Abbreviations

BRS	Behavioral Response Study
CEE	Controlled Exposure Experiment
photo-ID	photo-identification

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1. Cape Hatteras Photo-identification

In fieldwork supporting the Atlantic Behavioral Response Study (BRS) in 2020 (Southall et al. 2021), more than 17,000 digital images were collected in 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 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 six species, with most taken of 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 these images were cropped. Sighting data and photo-ID information were stored in an Access database managed by Kim Urian (Duke University Marine Lab).

Table 1. Cetacean sightings with the number of photo-ID images collected for each species in the Cape Hatteras study area in 2020.

Species	Common Name	Number of Sightings	Number of Photo-ID Images
Delphinus delphis	Common dolphin	2	4
Globicephala macrorhynchus	Short-finned pilot whale	47	2,058
Physeter macrocephalus	Sperm whale	1	36
Stenella frontalis	Atlantic spotted dolphin	3	54
Tursiops truncatus	Bottlenose dolphin	15	37
Ziphius cavirostris	Cuvier's beaked whale	81	15,400
Total		**149**	**17,589**

Images of 70 newly identified animals were added to photo-ID catalogs of short-finned pilot whales (*Globicephala macrorhynchus*) and Cuvier's beaked whales, and 42 new photo-ID matches were made within these two catalogs. To date, photo-ID catalogs for 11 species have been assembled in the Cape Hatteras study area, across multiple Atlantic Fleet Testing and Training monitoring projects, with 558 individuals re-sighted across all species (**Table 2**).

Table 2. Summary of images collected during fieldwork in the Cape Hatteras study area in 2020, 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	4	0	46	0	1
Globicephala macrorhynchus	2,058	51	1,311	27	463
Grampus griseus	1	0	46	0	6
Kogia sp.	0	0	1	0	0
Megaptera novaeangliae	0	0	2	0	0
Physeter macrocephalus	36	0	20	0	1
Stenella clymene	0	0	3	0	0
Stenella frontalis	54	0	24	0	0
Tursiops truncatus	37	0	349	0	19
Ziphius cavirostris	17,589	19	196	15	68

1.1 Cuvier's Beaked Whales

Nineteen new identifications were added to the Cuvier's beaked whale photo-ID catalog during 2020. An additional 15 whales were re-sighted, with re-sightings occurring both within and between years. The current re-sighting rate for Cuvier's beaked whales in the Hatteras area is 35 percent, up from 30 percent in 2019. To date, 37 of the 68 (54 percent) re-sighted Cuvier's beaked whales have been documented in multiple years, and nine whales have been re-sighted more than three years apart (**Table 3**). Zca_002 was first seen in October of 2013; it was re-sighted almost five years later in August 2018. It was satellite-tagged (ZcTag074) in 2018 and re-sighted a year later in June 2019. Based on photographs of its erupted teeth, we believe this animal is an adult male. Zca_008r was first observed in May 2014, and was seen again in October 2014 with a small calf, confirming her identity as an adult female. She was photographed in May 2016 without her calf, satellite-tagged (ZcTag047) and seen two days after tagging. During 2017, we photographed her on two occasions, in June and August, and in 2018, she was photographed on four occasions in May and August. This female represents the Cuvier's beaked whale with the most re-sightings off Cape Hatteras, with 10 sightings made over four years.

Fourteen Cuvier's beaked whales were tagged in 2020; four of the tagged individuals were matched to the photo-ID catalog. ZcTag098 was photographed twice in August 2018 and satellite-tagged in July 2020. ZcTag099 was seen in June and August of 2017 and tagged in July 2020. In addition, another two Cuvier's beaked whales that were tagged in 2020 had been previously photographed and satellite-tagged. ZcTag046 was tagged in May of 2016 and was re-sighted in 2017 and in 2020 when it was satellite-tagged again (ZcTag103). ZcTag089 was tagged in June 2019; it was sighted in August 2020 without its original satellite tag and was tagged for a second time (ZcTag109; **Figure 1**).

We paid particular attention to identifying the Cuvier's beaked whales involved in the Controlled Exposure Experiments (CEEs) in 2020. The focal whale in the first CEE (#2020_01) was ZcTag098; this whale was first sighted on two consecutive days in August 2018 and was re-sighted and tagged in July 2020 (**Figure 2**). ZcTag099 and ZcTag100 were focal animals in the second CEE (#2020_02). ZcTag099 was initially photographed in June 2017; it was re-sighted in August 2017 and subsequently re-sighted and satellite-tagged in July 2020 (**Figure 3**). ZcTag100 had not been previously seen in the Cape Hatteras area. The two focal Cuvier's beaked whales in the third CEE (#2020_03) were ZcTag108 and Zc20_232a. Zca_20_232a was first seen and satellite-tagged in August 2018 (ZcTag071) and re-sighted and DTagged in August 2020 (**Figure 4**). It was not carrying a satellite tag at the time of the DTagging. The first sighting of ZcTag108 was in August 2020 when it was satellite-tagged.

We have observed individual Cuvier's beaked whales associating in the same groups over relatively short time periods (days to weeks), but we have not found evidence of long-term social associations for this species. We have only documented one instance of Cuvier's beaked whales in the Cape Hatteras area associating with each other over extended periods of time. Zca_024 and Zc_008r were satellite-tagged in the same group in May 2016 (ZcTag046 and ZcTag047, respectively) and were seen together again in June 2017. We have confirmed that Zca_008r is an adult female and that Zca_024 is an adult male.

We have also reached out to other scientists and naturalists working in the area to determine whether they held any images of Cuvier's beaked whales that we could attempt to match to our catalog. For example, in November 2019, Danielle Waples met with Kate Sutherland, a scientist who works aboard the vessel *Stormy Petrel*, captained by Brian Patteson, out of Hatteras. This vessel is used for pelagic birding trips, during which beaked whales are encountered frequently. These trips are conducted south of Cape Point, well out of our study area. Kate contributed approximately 65 images of Cuvier's beaked whales taken during their pelagic seabird cruises from 2003 to 2018. We graded these images for photo quality and animal distinctiveness and created a new catalog that consists of 18 Cuvier's beaked whales. To date, we have made one match between the two catalogs. M-001 was photographed by Brian Patteson in May 2018. It was re-sighted by Duke researchers in August 2020 when it was satellite-tagged (ZcTag102; **Figure 5**). We will continue to compare our two catalogs to determine how frequently the Cuvier's beaked whales we observe during the BRS move south around Cape Point.

We are planning to contribute our sighting history data from Cuvier's beaked whales to a project co-ordinated by Erin Falcone and Greg Schorr. A proposal to support this project has been submitted to the Office of Naval Research. This is a collaborative project involving multiple scientists with the goal of comparing vital rates of Cuvier's beaked whales across populations. Data will be contributed from several well-studied populations of this species around the world that experience a range of military sonar activity. Pigmentation and scarring-density metrics will be applied uniformly to all images in the participating photo-ID catalogs and each Cuvier's beaked whale will be classified to age (calf, adult or juvenile) and 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 Hatteras photo-ID catalog is the largest in this dataset and will be an extremely important contribution to this comparative analysis.

Table 3. Photo-ID matches by year of Cuvier's beaked whales re-sighted over multiple years in the Cape Hatteras study area, 2013–2020.

ID[1]	Year							
	2013	2014	2015	2016	2017	2018	2019	2020
Zca_001r	X		X					
Zca_002 (ZcTag074)	X					X^m	X^m	
Zc_003		X				X		
Zca_003r (ZcTag029)		X^m				X		
Zca_005		X	X		X			
Zca_006 (ZcTag040)		X	X		X	X		
Zca_008r (ZcTag047)		X^y		X^m	X^y	X^y		
Zca_015 (ZcTag039, ZcTag077)			X			X		
Zca_016			X				X	
Zca_019 (ZcTag043)		X	X					
Zca_020			X				X	
Zca_024 (ZcTag046, ZcTag103)				X	X			X^m
Zca_027r			X			X		
Zca_030 (ZcTag055)					X^y		X^m	
Zca_031 (ZcTag056)					X		X	X
Zca_032					X	X^m		
Zca_035 (ZcTag076)					X	X^y		
Zca_035r (ZcTag048)				X		X		
Zca_038					X	X		
Zca_040					X^y		X	
Zca_044r				X		X^m		
Zca_048					X		X	
Zca_050r (ZcTag057)					X	X		
Zca_051r (ZcTag058)					X^y	X^m		
Zca_052 (ZcTag084)						X	X^m	X
Zca_054r					X^y		X	
Zca_055 (ZcTag071)						X		X
Zca_056 (ZcTag072)						X		X
Zca_059r					X	X^y		
Zca_071r (ZcTag081)					X	X^m		
Zca_074r					X	X		
Zca_078 (ZcTag089, ZcTag109)							X	X
Zca_082r						X	X	
Zca_099r (ZcTag083)						X^m	X	
M-002		X	X					

ID[1]	Year							
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
M-003		X	X					
M-004	X				X			

[1] Zca=*Ziphius cavirostris* (Cuvier's beaked whale); M=aerial-vessel match to University of North Carolina at Wilmingtom catalog

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

Figure 1. Photographs of ZcTag089 during a) satellite-tagging in June 2019 and b) re-sight and second satellite tagging in August 2020 (ZcTag109).

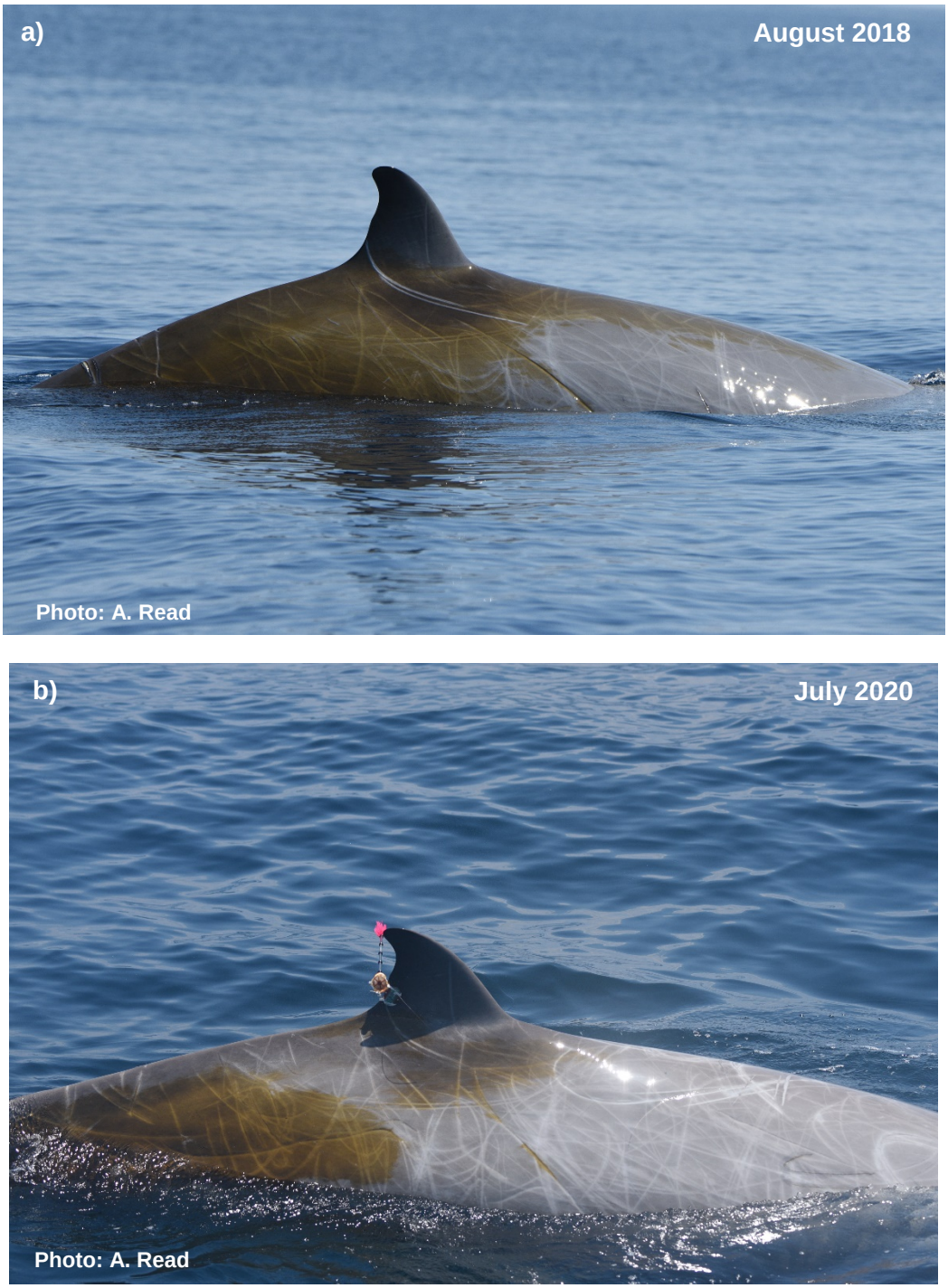

Figure 2. Photographs of ZcTag098 in a) August 2018 and b) re-sight and satellite tagging in July 2020 (ZcTag098).

Figure 3. Photographs of ZcTag099 in a) August 2017 and b) re-sight and satellite tagging in July 2020 (ZcTag099).

Figure 4. Photographs of ZcTag071 during a) satellite-tagging in August 2018 and b) re-sight and DTagging in August 2020 (Zc_20_232a).

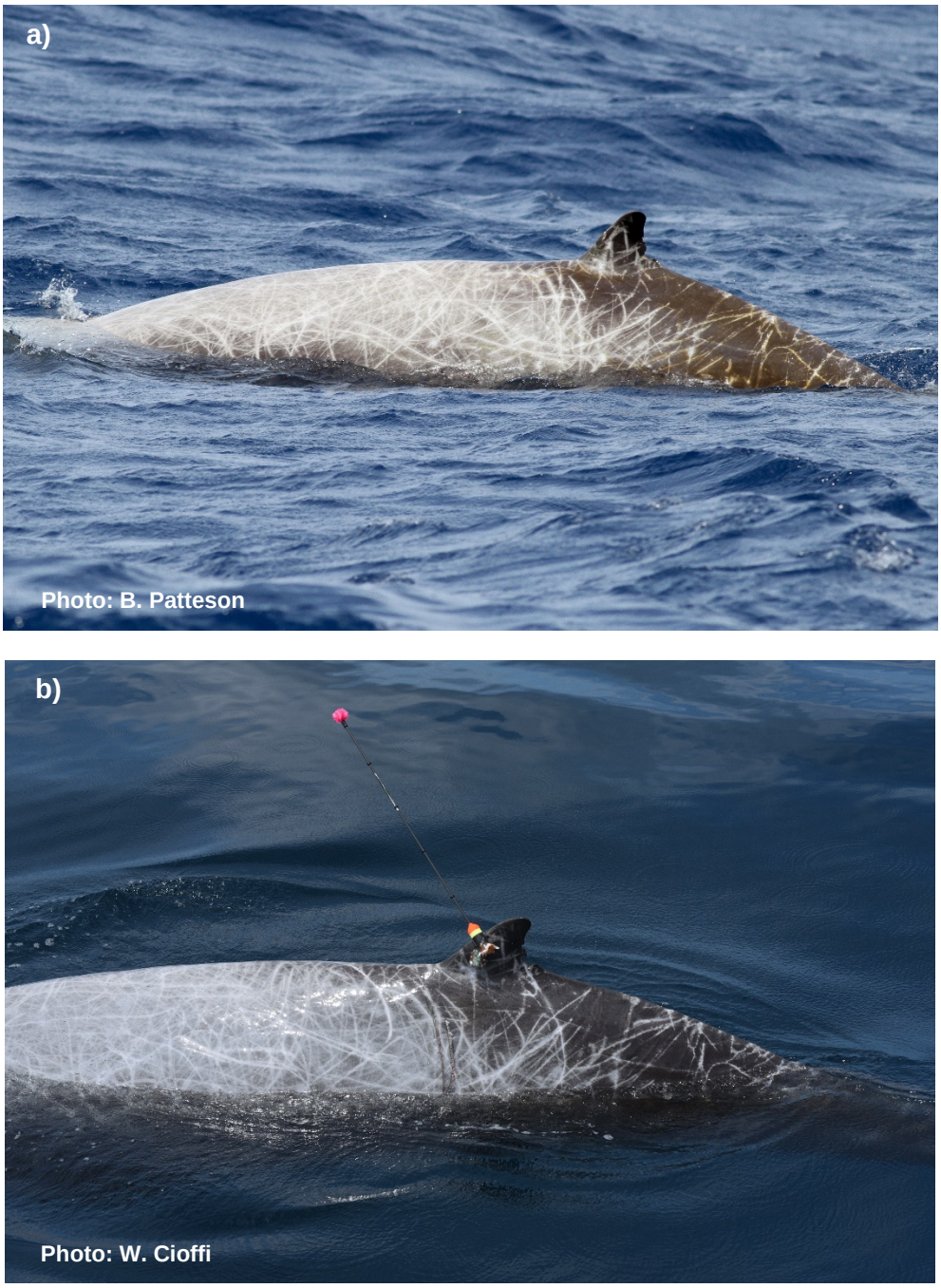

Figure 5. Photographs of M-001 a) south of Cape Point in May 2018 and b) north of Cape Point where it was satellite-tagged in August 2020 (ZcTag102).

1.2 Short-finned Pilot Whales

Totals of 51 new identifications and 27 new re-sights were added to the short-finned pilot whale catalog in 2020. The current re-sight rate of short-finned pilot whales is 35 percent—up slightly from 34 percent in 2019. More than 200 short-finned pilot whales have been seen on three or more occasions, and 6 animals have been re-sighted more than seven times (**Table 4**). Most of the short-finned pilot whales with extensive sighting histories have either been tagged or biopsied (**Table 5**).

We also are documenting individual short-finned pilot whales that return to the Cape Hatteras study area over extended periods. More than 110 pilot whales have spans of at least five years between their first and last sightings, and 20 pilot whales have records that span a decade or more (**Table 6**). Gma_7-318 was first photographed off Hatteras, North Carolina, in May and August 2007. It was re-sighted by HDR scientists during surveys off Norfolk, Virginia, in November 2016 and was sighted again off Hatteras and satellite-tagged in May 2019 (GmTag223; **Figure 6**). With 12 years between its initial and most recent sighting, this satellite-tagged pilot whale has the longest sighting history in the Cape Hatteras area. These long-term records demonstrate that both male and female short-finned pilot whales exhibit strong, but perhaps intermittent, site fidelity to the Cape Hatteras area.

We have photographed many individual short-finned pilot whales in association over long periods. 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 of 2015. Another two pilot whales (Gma_9-010 and Gma_9-118) were photographed in the same group four times between 2007 and 2014. Gma_242du and Gma_6-116 (GmTag134 and GmTag135) were photographed in May 2015 with five other distinct pilot whales, and all seven were seen in the same group in August of 2018. We will continue to explore short-finned pilot whale social structure in the coming year.

The 51 newly identified short-finned pilot whales added to the Hatteras photo-id catalog were systematically compared to catalogs for this species from Onslow Bay and Jacksonville, Florida. We previously matched four pilot whales between the Hatteras and Onslow Bay study areas. Gma_8-165 was seen in Onslow Bay, North Carolina, in a group of 40 short-finned pilot whales in August of 2007 and re-sighted and satellite-tagged (GmTag209) in the Cape Hatteras area 11 years later in August of 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 Hatteras and Jacksonville catalogs.

Table 4. Frequency distribution of the number of sightings of photo-identified short-finned pilot whales in the Cape Hatteras study area.

Number of Sightings	Number of Individuals
1	848
2	260
3	98
4	59
5	24
6	8
7	8
8	4
9	1
10	0
11	1
Total	**1,311**

Table 5. Sighting histories of short-finned pilot whales seen seven or more times in the Cape Hatteras study area.

ID[1]	Year												
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Gma_6-011					X	X	X, B		X			X^y, S	
Gma_6-055		X						X	X		X	X^y, S	
Gma_6-078	X^y	X^m							X^m			X^m, S	
Gma_7-127		X		X		X^y, B, D		X				X^y, S	
Gma_7-174		X^m		X	X				X^m			X^m	
Gma_9-108	X, B	X				X						X^m	

m – re-sighted within same month
y – re-sighted within same year
B- biopsied
S- satellite-tagged
D- Dtagged

Table 6. Frequency distribution of the number of years between first and last sightings of photo-identified short-finned pilot whales in the Cape Hatteras study area.

Number of Years Between First and Last Sighting	Number of Individuals
Less than 1	133
1 to 2	49
2 to 3	44
3 to 4	55
4 to 5	70
5 to 6	17
6 to 7	21
7 to 8	40
8 to 9	13
9 to 10	1
10 to 11	13
11 to 12	7
Total	**463**

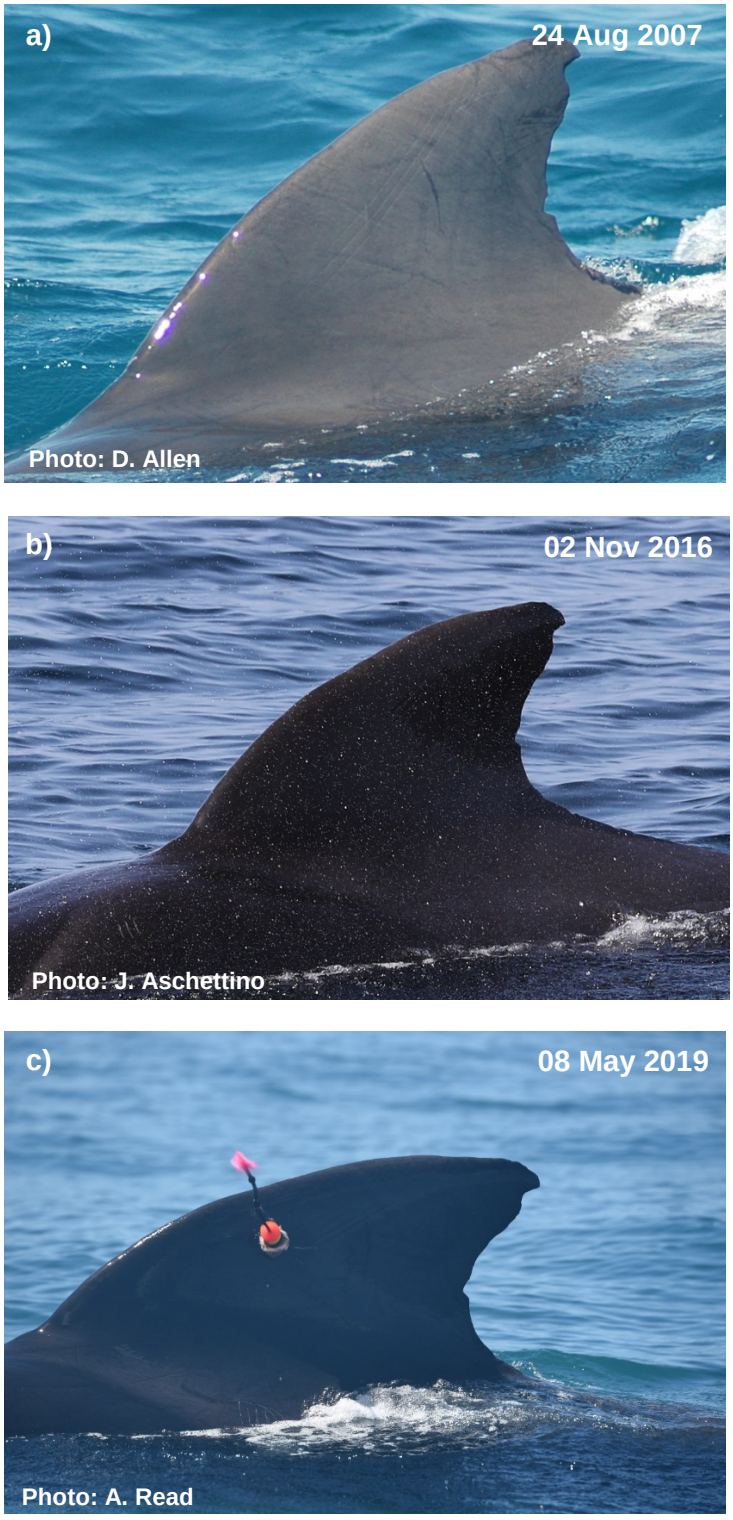

Figure 6. Photographs of Gma_7-318 a) in Hatteras in August 2007 and b) re-sighted in Norfolk in November 2016, and c) re-sighted and satellite-tagged in Hatteras in May 2019 (GmTag223).

Jessica Aschettino provided images of short-finned pilot whales collected by HDR researchers during their offshore field work in the vicinity of Norfolk Canyon from 2017-2019 (Engelhaupt et al., 2020), Virginia (**Table 7**). Approximately 4,400 images were graded 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.

A total of 101 new individuals was added to the Norfolk short-finned pilot whale catalog and four pilot whales were re-sighted (**Table 8**). Gma_1-008, Gma_7-041 and Gma_7-054 were initially sighted in the same group in July of 2016 and were re-sighted in the same group in July 2017. Gma_7-020 was first photographed in September 2015 and it was re-sighted in October 2019. This is the longest re-sight for a short-finned pilot whale in the Norfolk Canyon area. A total of seven short-finned pilot whales have been re-sighted by HDR researchers during their field work from 2015 through 2019.

Individual short-finned pilot whales in the Norfolk catalog were compared to the Hatteras short-finned pilot whale catalog, which contains 1,311 individuals. Sixteeen new matches were made between the two areas, adding to the 24 matches that had been previously made (**Table 9**). Thus, 17 percent (40 of 232) of pilot whales observed in the Norfolk Canyon region have also been photographed in the Cape Hatteras area. Comparing the two catalogs provides additional long term re-sighting information; 13 of the pilot whales were seen in Hatteras from 2007 to 2009, but not observed again until they were photographed in the Norfolk Canyon.

The cross-catalog comparisons also provide interesting information on patterns of social associations. For example, M-015 and M-016 were first seen in Hatteras in June 2015, then were re-sighted together in Norfolk in June 2016 and finally were sighted a third time together in Hatteras in October 2017. M-001, M-002 and M-003 were in the same group in Hatteras in June 2014 and re-sighted together in Norfolk Canyon in October 2015. These long-term associations confirm the strong social bonds amongst individual pilot whales in this strongly matrifocal species.

Examining photos of short-finned pilot whales taken in the Norfolk Canyon area also assists with our efforts to monitor satellite-tagged animals (see additional results below). Six satellite-tagged pilot whales have been photographed by HDR researchers after they were tagged off Hatteras. M-041 (GmTag096) was satellite-tagged in Hatteras in 2014 and was re-sighted in Norfolk in 2017; at that time the satellite tag had been shed but two pieces of attachment hardware were still present in the dorsal fin. This whale was photographed again in Hatteras in 2018 with only one piece of hardware remaining in the dorsal fin (**Figure 7**).

Comparing photo-ID catalogs also provides information about the long-distance movements of this population of short-finned pilot whales. M-042 was first photographed in Hatteras in May 2007. We matched it to a catalog of short-finned pilot whales that we created from images taken during research cruises conducted by National Oceanic and Atmospheric Administration scientists in the Gulf of Mexico in 2004. This pilot whale was re-sighted in the Norfolk Canyon area in January 2019, almost 15 years after its initial sighting. This is the longest term photo-ID match we have made to date (**Figure 8**). This animal also represents the longest geographic distance between any photo-ID matches we have made (**Figure 9**).

Table 7. Number of sightings of short-finned pilot whales and number of images collected by year in the Norfolk Canyon area.

Year	Number of Sightings	Number of Photo-ID Images
2017	28	1,894
2018	14	1,157
2019	28	1,276
Total	**70**	**4,327**

Table 8. Catalog sizes for short-finned pilot whales in the Norfolk Canyon area, including the original 2015-2016 catalog and individuals added during recent photo-ID efforts.

Species	2015-2016 Catalog	New IDs (2017-2019)	Current Catalog Size	New Re-sights	Total Re-sights
Globicephala macrorhynchus	131	101	232	4	7

Table 9. Photo-ID matches by year of individual short-finned pilot whales, 2007–2019, between the Cape Hatteras study area (HAT) and the Norfolk Canyon study area (NOR).

ID[1]	Year												
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
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			
M-028									HAT		NOR		
M-029									HAT		NOR		
M-030									HAT		NOR		
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		

ID[1]	Year												
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
M-041 GmTag096		HAT		HAT		HAT[y]		HAT			NOR	HAT[y]	
M-042	HAT[m]												NOR
M-043				HAT		HAT[m]	HAT				NOR		

m – re-sighted within same month

y – re-sighted within same year

Figure 7. Photographs of M-041 a) in Norfolk Canyon in July 2017 and b) re-sighted in Hatteras in August 2018.

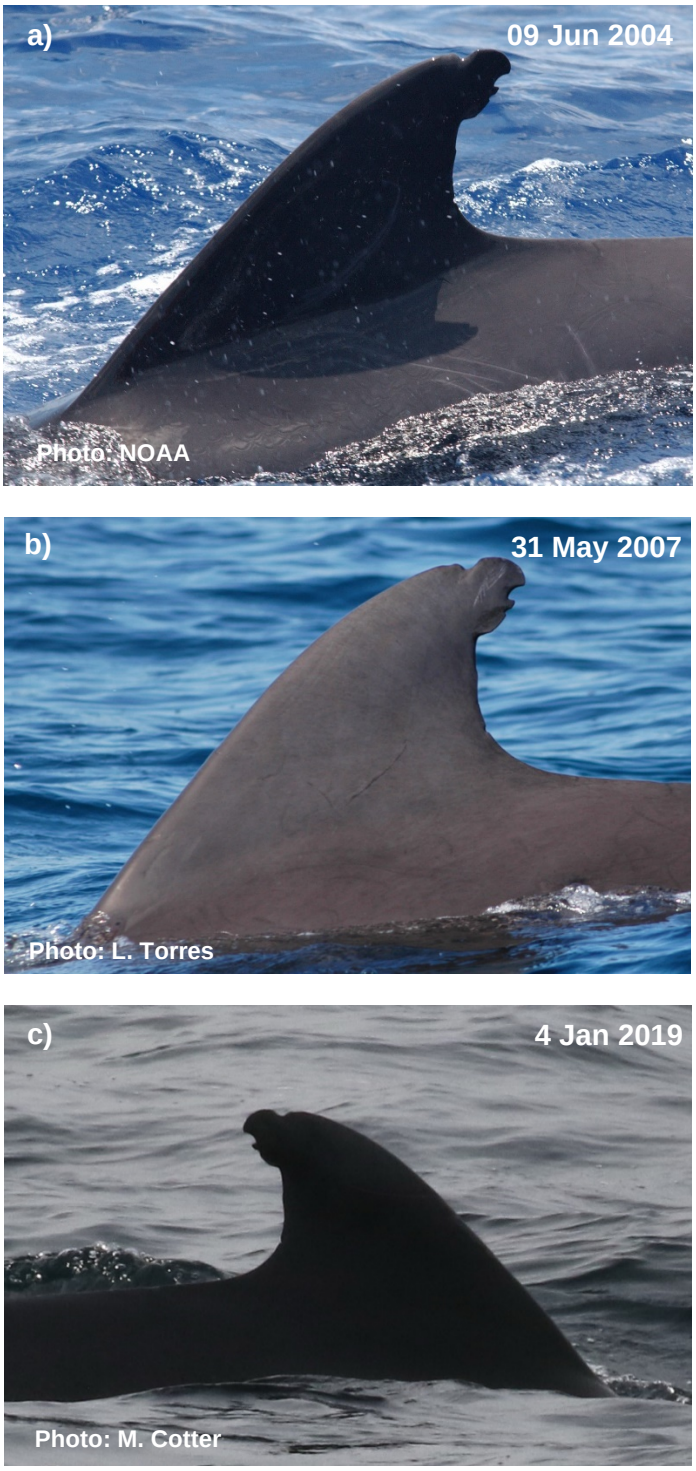

Figure 8. Photographs of M-042 a) in the Gulf of Mexico in June 2004, and b) re-sighted in Hatteras in May 2007 and c) re-sighted in Norfolk Canyon in January 2019.

Figure 9. Sighting locations of M-042 in the Gulf of Mexico (June 2004), off the coast of Cape Hatteras, North Carolina (May 2007), and off the coast of Virginia near Norfolk Canyon (January 2019).

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 satellite-tagged 72 Cuvier's beaked whales between 2014 and 2020, and resighted 42 of these animals (58 percent). Most re-sightings occurred within the same field season, but 16 (38 percent) were re-sighted over multiple years. We tagged the first Cuvier's beaked whale in the Cape Hatteras area, ZcTag029, in May 2014. We resighted it five days later and then we photographed it again four years later in May 2018. Three Cuvier's beaked whales have been satellite-tagged multiple times. ZcTag039 was first observed and tagged in June 2015; it was re-sighted over three years later in August 2018 when it was satellite-tagged for a second time (ZcTag077). Two other Cuvier's beaked whales were also satellite-tagged for a second time during the 2020 field season. ZcTag046 was satellite-tagged in May 2016, re-sighted in 2017 and seen again in 2020 when it was tagged again (ZcTag103). ZcTag089 was initially tagged in June 2019; it was seen without the tag in August 2020 and it was satellite-tagged for a second time (ZcTag109).

To date, we have satellite-tagged 80 short-finned pilot whales off Cape Hatteras and resighted 30 of these animals (38 percent) (**Table 10**). Most of these re-sightings occurred within the same field season, but 11 (37 percent) have been re-sighted across multiple years. A single short-finned pilot whale has been satellite-tagged multiple times. GmTag198 was first seen in the Hatteras area in 2011 and it was observed and satellite-tagged in 2018 and seen twice more that field season. It was seen in July 2019 and was satellite-tagged again (GmTag227; **Figure 10**).

In the summer of 2020 Joe Day, a student from Savannah State University, participated in the National Science Foundation Research Experience for Undergraduates program at the Duke Universtiy Marine Lab. His research efforts focused on documenting the long-term fate of satellite tags deployed on short-finned pilot whales. We identified eight satellite-tagged pilot whales that had been re-sighted at least 100 days after tag deployment and for which we had photos of the tagged side of the animal. We examined all good-quality photos from the relevant sightings for each individual.

We created a spreadsheet to score metrics of satellite-tag effects based on Andrews et al. (2019). Metrics included the presence of hardware in the dorsal fin, any signs of swelling and/or trauma to the dorsal fin or body and any physical damage done to the dorsal fin. We asked Bill McLellan, a scientist from the University of North Carolina at Wilmington, to participate in this assessment. Joe Day, Bill McLellan and Danielle Waples evaluated the tagging and re-sight images and scored these metrics for each pilot whale. In cases in which there was not consensus among the reviewers, Andy Read also evaluated the images and we reached a consensus score (**Table 11**).

None of the eight short-finned pilot whales showed physical damage to their dorsal fins, and in all cases the satellite tag had been shed. However, only one pilot whale had no noticeable effect whatsoever from the satellite tagging. One other whale had hardware remaining in its dorsal fin but no evidence of swelling; this whale, GmTag158, was tagged in May 2016 and re-sighted and photographed by HDR researchers in the Norfolk Canyon area in August 2017 (**Figure 11**). Three pilot whales had some swelling around the tag location but all hardware had been shed and the dorsal fins were well healed (**Figure 12**). And, finally, three pilot whales still had tag hardware in

their dorsal fins and swelling around the hardware (**Figure 13**). We plan to apply these same scoring criteria to the images of satellite-tagged Cuvier's beaked whales.

Table 10. Photo-ID re-sighting histories of cetaceans satellite-tagged in the Cape Hatteras study area. A red X denotes the year when satellite tagging occurred for that individual.

ID	Year						
	2014	2015	2016	2017	2018	2019	2020
GgTag017			X[m]				
GmTag087	X[y]						
GmTag089	X	X					
GmTag091	X	X					
GmTag096	X			X	X		
GmTag097	X	X					
GmTag122		X[m]					
GmTag127		X[m]					
GmTag134^		X			X		
GmTag135^		X[y]			X	X	
GmTag136		X[y]			X		
GmTag140		X		X			
GmTag157			X	X			
GmTag172				X[m]			
GmTag175				X[m]			
GmTag179				X	X		
GmTag182				X[m]			
GmTag197					X[y]		
GmTag198 (GmTag227)					X[y]	X	
GmTag199					X[m]		
GmTag201					X[y]		
GmTag203					X[y]		
GmTag204					X[y]		
GmTag205					X[y]		
GmTag206					X[y]		
GmTag207					X[m]		
GmTag208					X[m]		
GmTag216					X[m]		
GmTag218					X[m]		
GmTag223						X[m]	
GmTag226						X[y]	
TtTag015	X[m]						
ZcTag029	X[m]				X		

ID	Year						
	2014	2015	2016	2017	2018	2019	2020
ZcTag039 (ZcTag077)		X			X		
ZcTag040		X		X	X		
ZcTag046 (ZcTag103)			X	X			X^{m}
ZcTag047			X^{y}	X^{y}	X^{y}		
ZcTag048			X		X		
ZcTag054				X^{y}			
ZcTag055				X^{y}		X^{m}	
ZcTag056				X		X	X
ZcTag057				X	X		
ZcTag058				X^{y}	X^{m}		
ZcTag062				X^{m}			
ZcTag069					X^{y}		
ZcTag071					X		X
ZcTag072					X		X
ZcTag073					X^{y}		
ZcTag074					X^{m}	X	
ZcTag075					X^{m}		
ZcTag076					X^{m}		
ZcTag078					X^{m}		
ZcTag080					X^{m}		
ZcTag081					X^{m}		
ZcTag082						X^{y}	
ZcTag084						X^{m}	X
ZcTag085						X^{y}	
ZcTag086						X^{y}	
ZcTag087						X^{m}	
ZcTag088						X^{m}	
ZcTag089 (ZcTag109)						X^{m}	X
ZcTag090						X^{y}	
ZcTag091						X^{m}	
ZcTag092						X^{y}	
ZcTag093						X^{y}	
ZcTag095						X^{m}	X

ID	Year						
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
ZcTag096						X[m]	
ZcTag097						X[m]	
ZcTag102							X[m]
ZcTag103							X[m]
ZcTag104							X[m]
ZcTag105							X[m]
ZcTag106							X[m]
ZcTag108							X[m]

[1] Ggr= *Grampus griseus* (Risso's dolphin); Gma= *Globicephala macrorhynchus* (short-finned pilot whale); Ttr=*Tursiops truncatus* (bottlenose dolphin); Zca=*Ziphius cavirostris* (Cuvier's beaked whale)

m – re-sighted within same month

y – re-sighted within same year

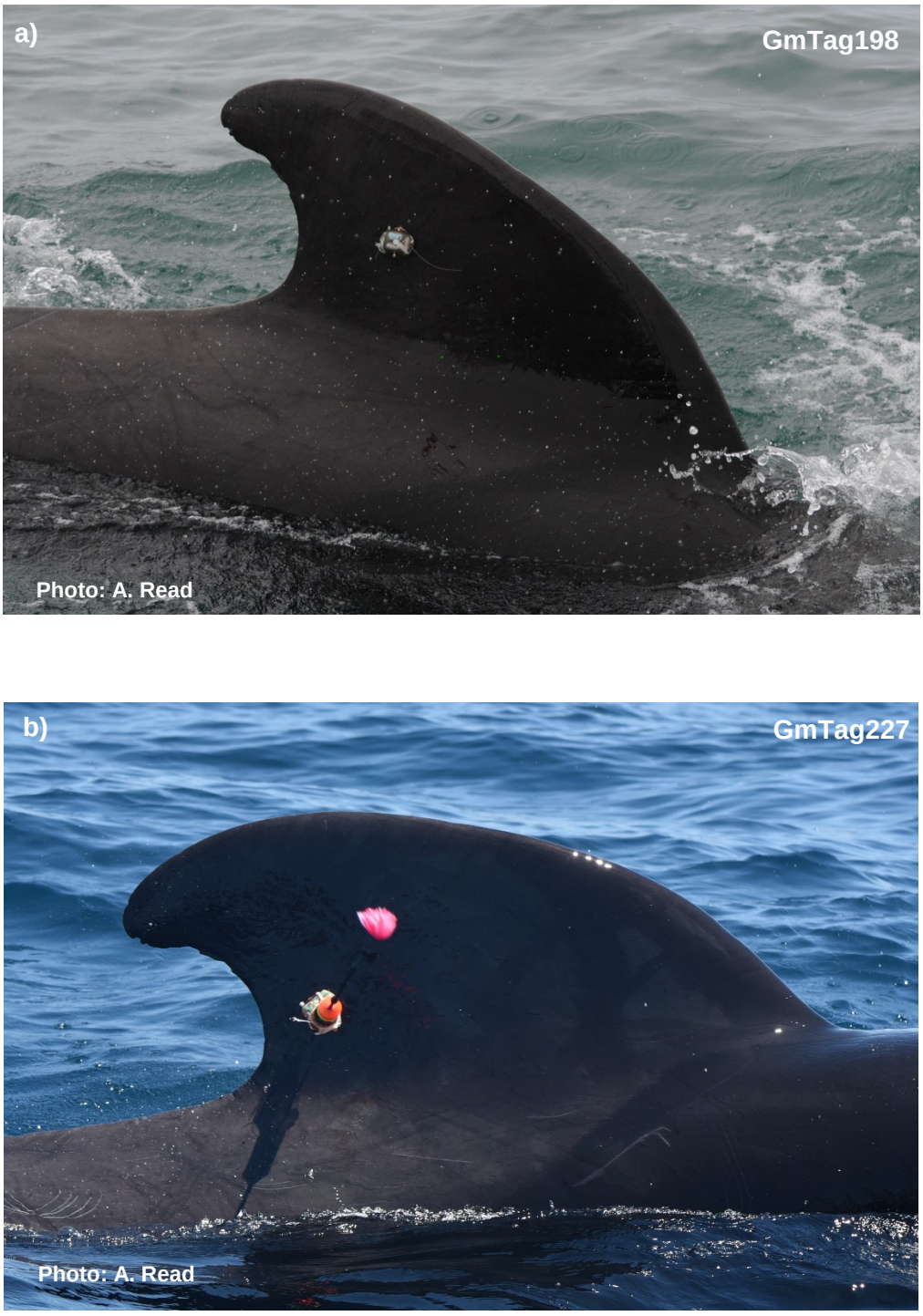

Figure 10. Photographs of GmTag198 during a) satellite-tagging in May 2018 and b) re-sight and second satellite tagging in July 2019 (GmTag227).

Table 11. Summary of the effect of satellite tags on short-finned pilot whales with at least 100 days between tagging and re-sighting.

Animal ID	No Effect of Tagging	Swelling	Hardware Present	Swelling and Hardware Present
GmTag091	Yes			
GmTag096				Yes
GmTag097				Yes
GmTag135		Yes		
GmTag136		Yes		
GmTag157		Yes		
GmTag158			Yes	
GmTag179				Yes
Total	**1**	**3**	**3**	**1**

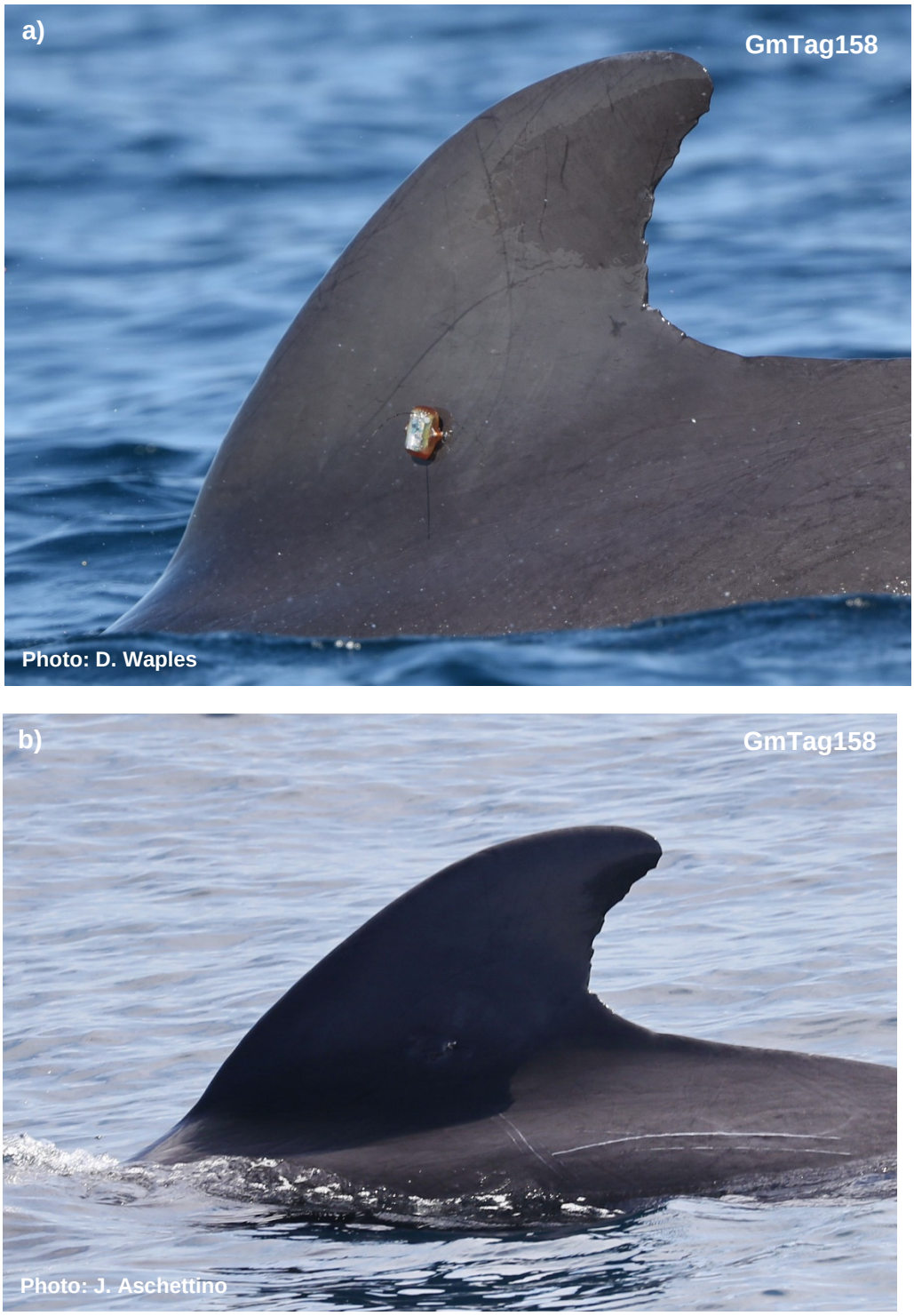

Figure 11. Photographs of GmTag158 during a) satellite-tagging in May 2016 and b) re-sight in August 2017.

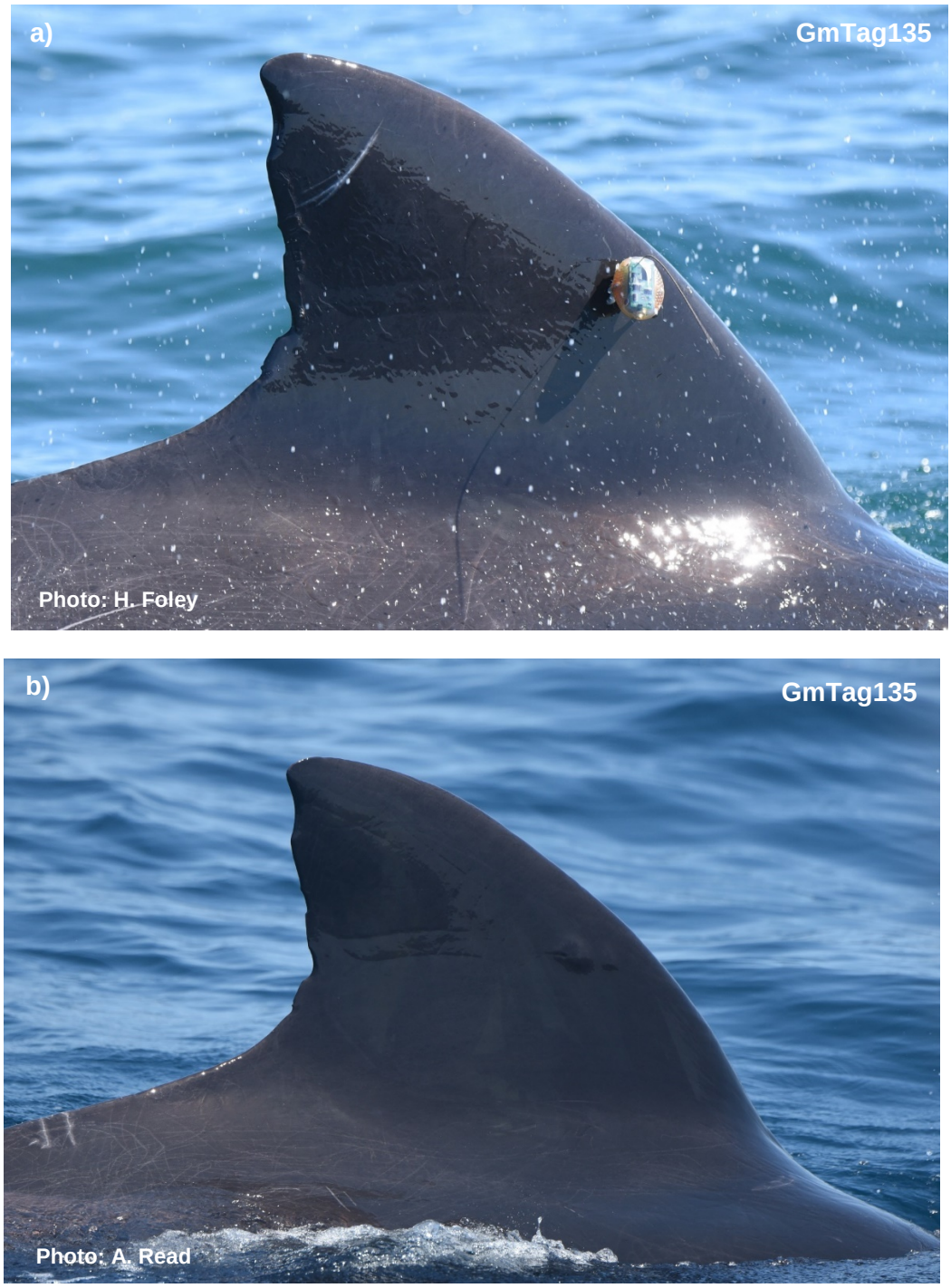

Figure 12. Photographs of GmTag135 during a) satellite-tagging in October 2015 and b) re-sight in July 2019.

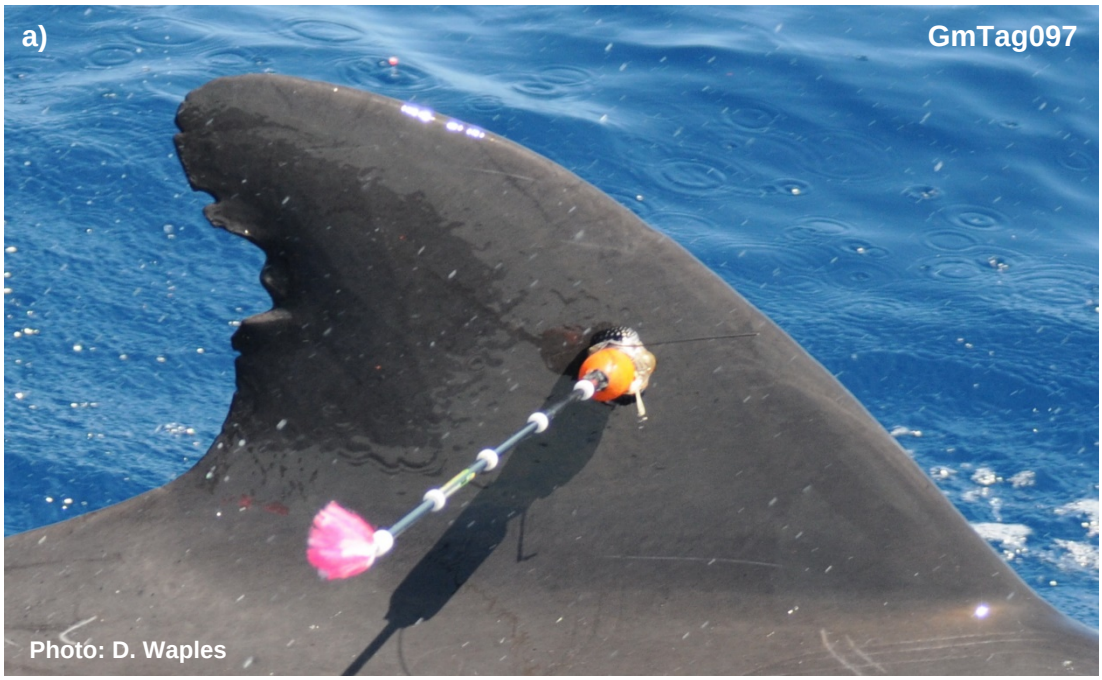

Figure 13. Photographs of GmTag097 during a) satellite-tagging in September 2014 and b) re-sight in May 2015.

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