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Pathology of short-term dorsal fin tag-attachments in tagged and re-stranded short-beaked common dolphins *Delphinus delphis* on Cape Cod, MA

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ABSTRACT: Odontocetes are difficult to study in the wild, making tagging and remote tracking a valuable practice. However, evaluations of host responses at tagging sites have been primarily limited to visual observations in the field. Here we explore the macro- and microscopic pathology of dorsal fin tag attachments in 13 stranded and released short-beaked common dolphins *Delphinus delphis* from Cape Cod, MA that later re-stranded and died or were euthanized 1–28 d post-tagging. Tags were attached to stranded dolphins' dorsal fins using 2 methods: core biopsy or piercing. Grossly, the piercing method resulted in epidermal compression into the dermis. One tag site had a necrotic border 28 d after application. Grossly, the biopsy method resulted in minimal to no tissue reaction. Two tag sites had granulation tissue accumulation 4 and 12 d after tagging. Histopathologic findings for all tag types and animals consisted of focal epithelial loss, dermal edema, perivascular edema, inflammation and hyperplasia, and inter- and extracellular edema in the adjacent epidermis. Minor expected pathological changes given the procedure were also observed: superficial epidermal necrosis in 3 cases, and superficial bacterial colonization in 2 cases. There was no evidence of sepsis and tagging was not related to cause of re-stranding or death in any case. These gross and histopathologic findings support previous observational conclusions in small delphinids that with appropriate sterile technique, the impacts of single pin dorsal fin tagging on the animal can be minimal and localized. Of the 2 methods, core biopsy may be a better tagging method.

KEY WORDS: Odontocete · Dolphin · Tag · Pathology · Stranding · Telemetry

1. INTRODUCTION

Free-swimming odontocetes are challenging to study because of infrequent and short duration surfacing and vast travel distances. Therefore, tagging enables study of movements, dive behavior, and habitat use, informing cetacean conservation and management policies (Andrews et al. 2019). Tagging live-stranded cetaceans prior to re-flotation, relocation and release, or release after rehabilitation is common practice in the USA (Whaley & Borkowski 2009) to document post-release survival, especially when satellite-linked telemetry is employed (Wells et al. 2008, Sampson et al. 2012, Sharp et al. 2014, 2016).

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Many advances have been made in the design of temporary satellite transmitters attached to small cetacean dorsal fins in recent years (Balmer et al. 2011, Andrews et al. 2019), specifically a transition to more single pin tag attachment models as they have a smaller effect on the dorsal fin if tag migration occurs when compared to multi-pin tag attachment models. Follow-up studies to assess tag site tissue responses and the health of the tagged dolphins have primarily been performed via visual assessment from vessel-based surveys and in some cases, by recapture health assessment. Studies have reported little to no visible health impacts of fin tagging procedures on dolphins, including in re-sightings up to 20 yr after tagging with no apparent long-term detrimental effects (Irvine et al. 1982, Wells et al. 1998, Balmer et al. 2011, Ryan et al. 2022). Gross and histopathologic evaluation of dorsal fin tagging sites is limited since these samples are only available postmortem from animals that have previously been tagged. Such reports include 7 harbor porpoises tagged in Europe (Sonne et al. 2012, Heide-Jørgensen et al. 2017). Histopathologic lesions at these tag sites included cellular debris, inflammatory cells, fibrin, and clusters of bacteria around the perforations from the satellite tag attachment and throughout the path of tag migration. Reactions appeared to be more severe at tag sites that experienced caudal tag migration (Sonne et al. 2012). Further investigation into tag site healing and pathology is warranted to better inform tagging best practices and minimize associated health impacts on small cetaceans.

Live strandings of odontocetes on Cape Cod (MA, USA) are common (Bogomolni et al. 2010, Sampson et al. 2012, Sharp et al. 2014, 2016). Many of the stranded animals, especially those that strand in groups (mass strandings), are often healthy at the time of stranding and likely strand due to the large tidal fluxes and complex geography of the area. Short-beaked common dolphins *Delphinus delphis* are currently the most commonly stranded dolphin species in this area. Between 2012 and 2021, 503 live common dolphins mass- or single-stranded on Cape Cod and 318 (63%) of those were deemed healthy through a standardized health assessment, tagged, relocated and released (IFAW 2022). Approximately 11% (34/318) of these relocated and released dolphins later re-stranded.

In this study, we explore the pathology of dorsal fin tagging sites comparing 2 different tag attachment methods in stranded and released short-beaked common dolphins from Cape Cod that later restranded and died or were euthanized.

2. MATERIALS AND METHODS

2.1. Case inclusion criteria

Live *D. delphis* stranding cases on Cape Cod and southeastern Massachusetts that occurred between 2011 and 2021 were retrospectively analyzed for inclusion in this study. All strandings were managed by the Marine Mammal Rescue and Research Program of the International Fund for Animal Welfare (IFAW) under a stranding agreement with the National Oceanographic and Atmospheric Administration's National Marine Fisheries Service. Necropsy and histopathology reports were reviewed from live stranded *D. delphis* that were tagged, released, and later found dead or re-stranded alive and died or were euthanized due to declining health. Cases with notes on gross appearance of the tag site and/or samples of the tag site submitted for histopathology were included in this study.

2.2. Identification tags

Two different types of single pin identification tags were applied to *D. delphis* dorsal fins: global sheep or cattle ear tags (AllFlex Livestock Intelligence) that pierce the tissue with a sharp point allowing the tag pin to push through and seat on the opposite side of the fin (Fig. 1A), and FlexoPlus®Geno P/P Tissue Sampling tags (Caisley Eartag Limited) that collect a punch biopsy during tag application, removing a small core of the dorsal fin tissue as the tag is secured on the fin (Figs. 1B & 2B). These single pin identification tags will be referred to throughout by their method of attachment: 'piercing' for global ear tags and 'biopsy' for tissue sampling tags. ID tags were either soaked in cold sterile solution for 11 min (Cidex® OPA, Advanced Sterilization Products) and rinsed with sterile saline or soaked in a betadine solution for a minimum of 5 min prior to application. Dorsal fin tag sites were prepared with 3 alternating alcohol and betadine scrubs with a total contact time of approximately 5 min. Identification tags were attached 1–2 cm cranial to the trailing edge of the dorsal fin either in the proximal or distal third of the fin.

2.3. Satellite-linked tags

Two models of minimally invasive single-pin, location-only satellite-linked transmitters were deployed in this study: Kiwistat 202 Cetacean Fin Tags (Model K2F161; Sirtrack) (Fig. 1C) and SPOT 6 tags (Wildlife

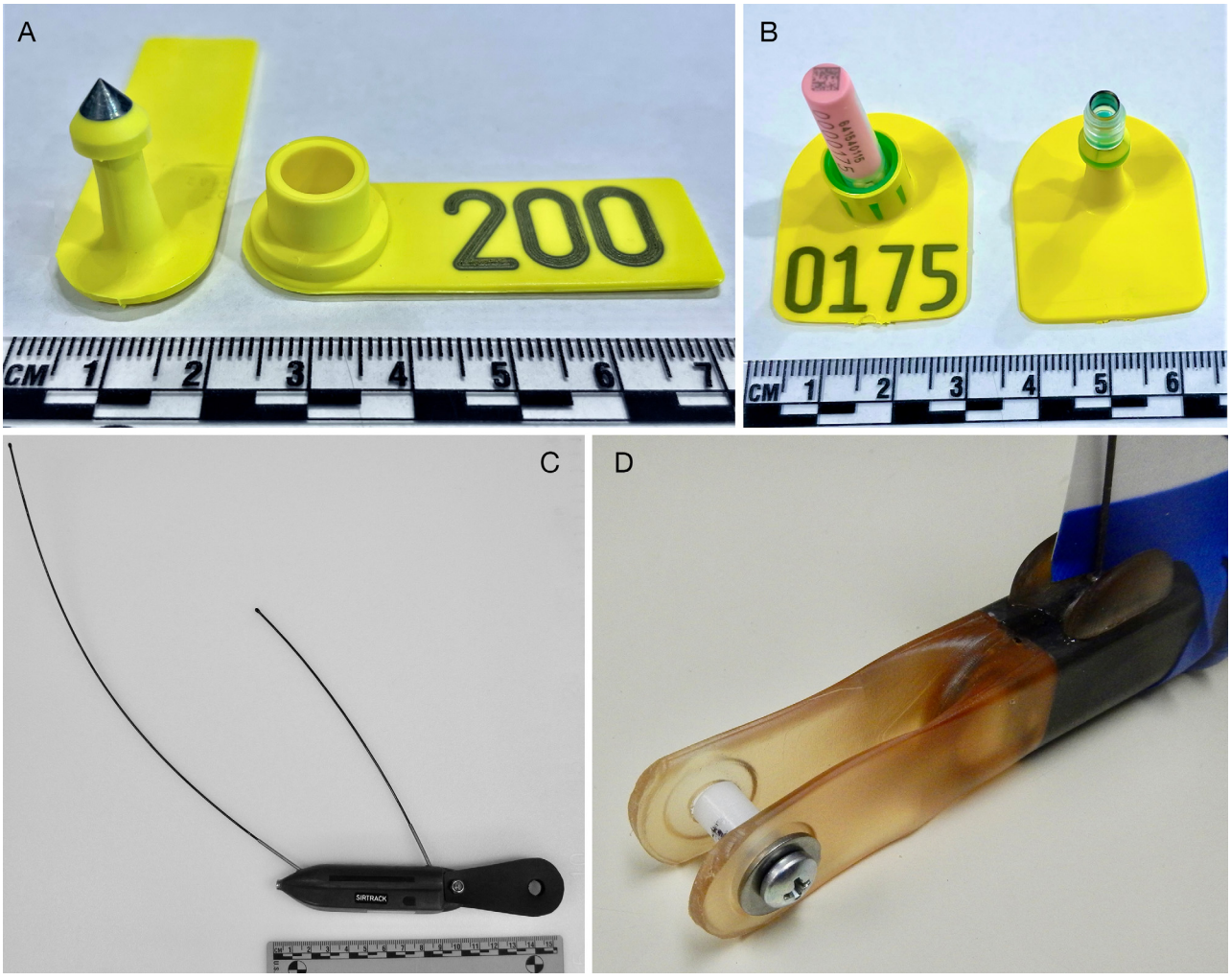

Fig. 1. Tags utilized in this study. (A) Piercing ID tag, (B) Biopsy ID tag, (C) Kiwisat 202 satellite tag (D) SPOT6 satellite tag

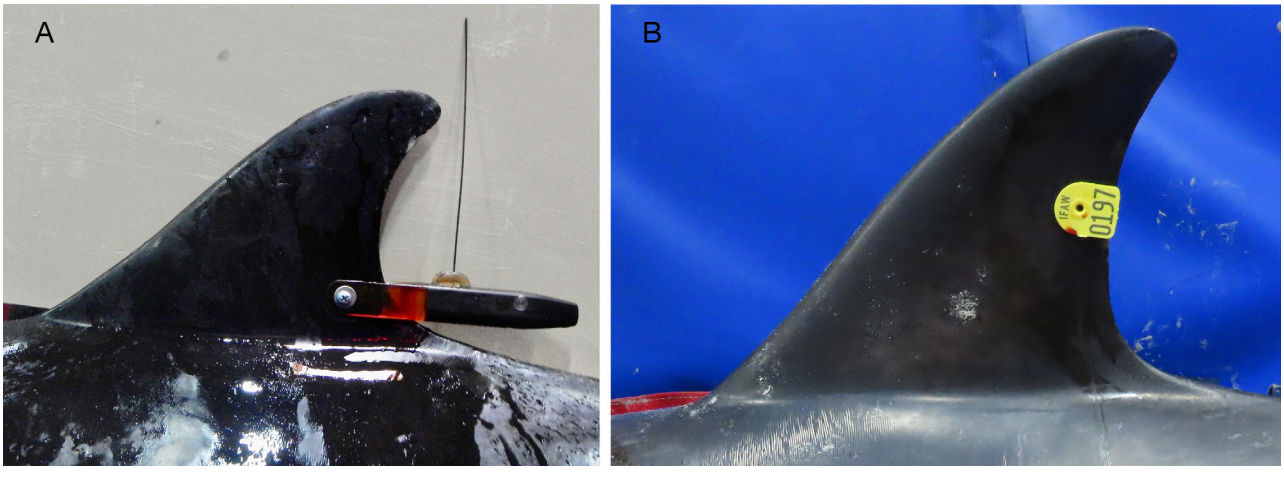

Fig. 2. (A) Case 9 with a SPOT 6 satellite tag attached to the dorsal fin with a Delrin pin after a biopsy core, prior to release. (B) Common dolphin with biopsy tag attachment with a highly flexible plastic pin

Computers) (Fig. 2A). Both of these tags had the same attachment method and were affixed to the proximal third of the dorsal fin, approximately 3 cm cranial to the trailing edge, based on previously published methods (Balmer et al. 2011, Sharp et al. 2014). In brief, the tag attachment site was aseptically prepared with betadine and alcohol surgical scrubs for a total contact time of 5 min. In some cases, a 3% Mepivacaine HCl (Patterson Dental Supply) L- or ring-block was applied around the tag site with a dental infuser to provide local analgesia while minimizing the area of dorsal fin affected. A hole was then drilled in the selected location using an 8 mm diameter cork-borer bit in a standard cordless drill. For additional local analgesia, after removal of the tissue core and prior to attachment of the tag, sterile lidocaine soaked swabs were placed within the cored site. All components in contact with the dorsal fin were cold sterilized in CIDEX® OPA and rinsed with sterile saline prior to application. To attach the satellite tag, a Delrin pin was inserted into the cored site and secured on either side of the tag flanges with stainless steel washers and zinc plated steel screws. This attachment configuration with dissimilar metals causes galvanic corrosion of the screw head and facilitates tag detachment following battery cessation after approximately 60 d.

2.4. Necropsy and histopathology

Necropsies were performed following protocols outlined in the Marine Mammal Necropsy Manual (Pugliares et al. 2007) and were led by IFAW staff biologists and veterinarians. Sexual maturity was determined by macro- and microscopic examination of the gonads with respect to size and sperm production (males) and evidence of current or previous pregnancies (females). A standardized set of tissue samples for histopathology were preserved in 10% neutral buffered formalin including brain, heart, spleen, liver, forestomach, fundic stomach, pyloric stomach, small intestine, colon, thyroid gland, skeletal muscle, lung, esophagus, lymph nodes, reproductive organs, and kidney. Case 10 had a modified sampling protocol as the carcass was frozen and subsequently thawed prior to sampling. In this individual, only the kidney, pancreas, and ovary were examined histologically, though a full gross examination was performed.

Histological slides were prepared by Histology Consultation Services (Everson, WA) and reviewed by Dr. David Rotstein, Consulting Veterinary Pathologist (Olney, MD) or prepared and reviewed by the Zoological Pathology Program at the Veterinary Diagnostic Laboratory of the University of Illinois at Urbana-Champaign.

3. RESULTS

Based on the inclusion criteria, 13 *Delphinus delphis* that stranded on or near Cape Cod, MA, USA between 2011 and 2021 were included in the study (Table 1). These 13 cases included a total of 17 tag attachments (2 types of tags were attached in 4 of the cases). Three dolphins were tagged with piercing identification tags, 2 with biopsy identification tags, 4 with satellite tags, and 4 with both a piercing identification tag and a satellite tag. The time between tagging and death ranged from 1 to 28 d (mean 7 d). Tag pathology was reported from macroscopic examinations in 2 cases (1 biopsy, 1 satellite tag), microscopic exams in 3 cases (2 piercing, 1 satellite tag), and both macroscopic and microscopic exams in 11 cases (4 piercing, 1 biopsy, 6 satellite tags). No data were reported for one piercing attachment.

Cause of death (COD) was determined for all cases included in this study based on gross necropsy and histopathologic evaluation. Two cases did not have an obvious clinical cause of stranding or death (undetermined COD). In 6/13 cases, the animals had no evidence of underlying chronic disease and cause of death was determined to be stranding-related (exertional rhabdomyolysis, stress cardiomyopathy, soft tissue -trauma, and aspiration). Attributed causes of stranding included verminous pneumonia (n = 2), nephrolithiasis (n = 1), brucellosis (n = 1), and verminous encephalitis (n =1). None of the cases had gross or histological changes at the tag sites considered sufficiently significant to have contributed to stranding or death such as thrombosis, infarction, infection, or marked inflammation.

No macroscopic tissue changes were noted in tag attachment sites in 7/17 tag sites (2/5, 40% piercing; 2/2, 100% biopsy ID; and 3/8, 37.5% biopsy satellite). One biopsy satellite tag site and one piercing tag site did not have a gross description available. The only case with macroscopically evident necrosis within a tag site was the piercing tag of Case 4, which was documented 28 d after attachment (Fig. 3A). The other gross tissue change observed in piercing tags was epidermal compression into the dermis, creating a moderate to marked depression immediately surrounding the tag attachment site (Fig. 3B). Three of 8 satellite tag sites (Cases 8, 9, 13)

Table 1. Demographics, tag type, duration of tag attachment, and available pathology data for 13 live-stranded and tagged *Delphinis delphis* cases from Cape Cod, MA that re-stranded and died or were euthanized. SL: straight length; NE: not examined

Case no.	Animal ID	Sex	SL (cm)	Sexual maturity	Tag type	Tagging–death interval (d)	Tag-site pathology (tag type)	
							Data	Histopathology
1	IFAW11-026Dd	M	187	Mature	Both (piercing ID & satellite tags)	1	Macroscopic (satellite tag)	NE
2	IFAW12-003Dd	F	200	Mature	Both (piercing ID + satellite tags)	10	Macro- and microscopic	Inter- and intracellular epidermal and/or dermal edema, superficial epidermal and/or dermal necrosis (both); perivascular edema (satellite)
3	IFAW12-033Dd	M	234	Mature	ID (piercing)	5	Macro- and microscopic	Focal epidermal loss, perivascular edema
4	IFAW12-196Dd	M	226	Mature	ID (piercing)	28	Macro- and microscopic	Superficial epidermal and/or dermal necrosis
5	IFAW16-243Dd	M	221	Mature	Both (piercing ID + satellite tags)	5	Macro- and microscopic	Epidermal hyperplasia at and adjacent to the tag site (satellite)
6	IFAW17-061Dd	M	224	Mature	Satellite	5	Macro- and microscopic	Perivascular neutrophilic inflammation
7	IFAW17-079Dd	M	141.3	Immature	ID (piercing)	7	Microscopic	No changes appreciated
8	IFAW19-081Dd	F	191	Mature	Both (piercing ID + satellite tags)	5 (ID), 4 (satellite)	Macro- (satellite) and microscopic	Focal epidermal loss, inter- and intracellular epidermal and/or dermal edema, superficial epidermal and/or dermal necrosis, superficial bacterial colonization (both)
9	IFAW19-083Dd	F	176	Immature	Satellite	12	Macro- and microscopic	Margins irregular, colonized by mats of bacteria
10	IFAW19-102Dd	F	197.4	Mature	ID (biopsy)	4	Macroscopic	NE
11	IFAW19-177Dd	M	174	Immature	Satellite	5	Microscopic	Mild hemorrhage
12	IFAW19-220Dd	F	148.4	Immature	ID (biopsy)	2	Macro- and microscopic	Mild perivascular hemorrhage
13	IFAW21-010Dd	F	216	Mature	Satellite	8	Macro- and microscopic	Inter- and intracellular epidermal and/or dermal edema, perivascular edema

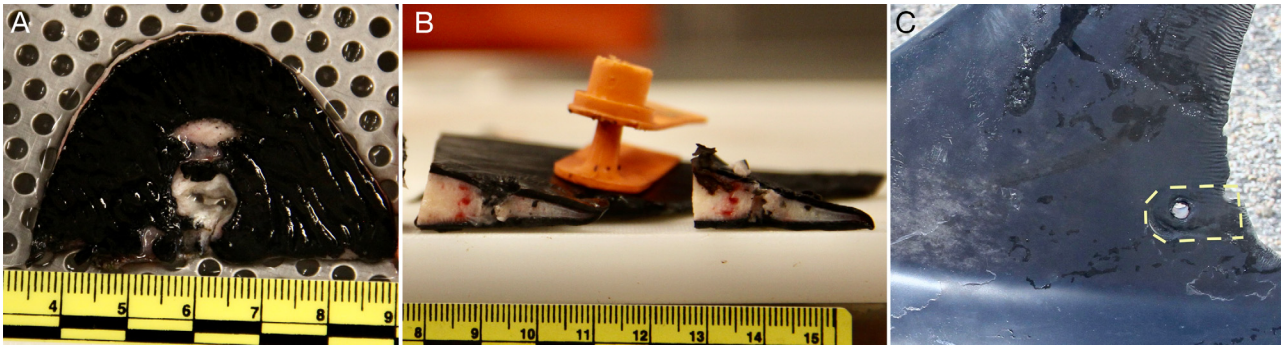

Fig. 3. (A) Case 4, lateral view of excised piercing tag site with grossly evident necrosis (erosion of the skin and tan discoloration of the underlying tissue, confirmed on histopathology); (B) Case 2, piercing tag site with epidermal compression into the dermis within the tag track. (C) Case 13, lateral view of left side of dorsal fin, after tag removal, showing tag attachment site with mild epidermal depression corresponding to the satellite tag flange (dashed yellow outlines)

had a mild depression (≤1 mm) in the epidermis surrounding the attachment hole corresponding to a portion of the attachment flanges (Fig. 3C). Mild erythema was seen at one satellite tag site (Case 6). Granulation tissue was noted in one satellite tag site (Case 9) 12 d post-tagging, and edema was noted in one satellite tag site (Case 8) 4 d post-tagging.

Histopathologic findings were available for tag sites ranging between 4 and 28 d post-tagging. For both types of attachment methods, the most common histopathologic findings were focal epidermal loss (Case 3, piercing; and Case 8, both), mild to moderate inter- and intra-cellular epidermal and/or dermal edema (Cases 2 and 8, both; and Case 13, biopsy satellite), mild perivascular edema (Cases 2 and 13, biopsy satellite; and Case 3, piercing), mild superficial epidermal and/or dermal necrosis (Cases 2 and 8, both; and Case 4, piercing) and mild superficial bacterial colonization (Case 8, both; and Case 9, biopsy satellite). A single case had mild epidermal hyperplasia at and adjacent to the tag site (Case 5, biopsy satellite), and one case exhibited mild perivascular neutrophilic inflammation (Case 6, biopsy satellite). Case 7 (piercing) did not have any microscopic changes associated with the tag site 7 d after tagging.

4. DISCUSSION

Overall, gross and histopathologic lesions associated with tag attachment on the dorsal fin of stranded and released *Delphinus delphis* in this study were minor and predominantly followed expected tissue healing patterns. The mild to moderate dermal and epidermal edema observed in 3 cases are normal sequelae that occur during the acute inflammatory phase of healing. Mild necrosis and bacterial colonization were also observed in a limited number of cases. Bacterial colonization did not extend into subepidermal tissues, was not accompanied by an inflammatory reaction (fibrin or neutrophils), and did not appear to be actively interfering with the healing process. The single case of mild perivascular inflammation near a satellite tag site was not accompanied by any bacteria or vasculitis. These minor lesions are not unexpected since the procedure involved the introduction of a sterile foreign body into the dorsal fin under field-sterile conditions, immediate return of the animal back into the ocean, and chronic drag forces exerted by the tag at the attachment site. In stranded dolphins that must be immediately relocated and released, these conditions are unavoidable, and the value of the post-release survival data provided by these tags greatly outweighs the minor micro- and macroscopic tissue changes observed within this study. Cold-sterilization was the disinfection choice for tags in this study and provides adequate disinfection. Gas sterilization, if available, could be considered to further reduce the chance of microbe contamination in the tagging protocol.

Although on a shorter timescale and less severe, the pathology findings in this study are in line with the published studies on multi-pin dorsal fin tag attachment sites from 7 harbor porpoises that were captured, satellite tagged and later either legally hunted or killed accidentally in fishing nets (Sonne et al. 2012, Heide-Jørgensen et al. 2017). Postmortem macroscopic observations of these harbor porpoise tag sites (attachment durations 84–767 d) included variable caudal migration of the attachment pins within the fins, variable epidermal covering of the attachment sites, fibrous scar tissue, and no evidence

of infection. Histopathology findings were available from 3 of these harbor porpoises with samples obtained 84, 343, and 408 d after tags were attached (Sonne et al. 2012, Heide-Jørgensen et al. 2017). Observed tissue reactions included cellular debris, inflammatory cells, fibrin and clusters of bacteria around the perforations from the satellite tag attachment and throughout the path of tag migration. All attached tags were multipin in those studies and tissue response was more severe in animals with caudal tag migration.

Both the identification and satellite tags in the current study had single-pin tag attachments. The lesions associated with caudal migration of these tags were less severe than those observed in the 3-pin tag attachments in harbor porpoises in the previously referenced studies (Sonne et al. 2012, Heide-Jørgensen et al. 2017). This was thought to be related to the single point of attachment and shorter attachment durations. Additionally, many of the 3-pin dorsal fin tags remained attached to the animal significantly longer than the battery life of the tag, meaning that tag attachment outlasted the data transmission period (Heide-Jørgensen et al. 2017). This prolonged attachment creates unnecessarily protracted impacts on the animals. The benefit of bigger telemetry datasets provided by multipin tag attachments must be weighed against the greater potential impact to the animal. Whenever possible, attachment duration should closely match battery life to prevent unnecessary impacts on the animals.

More severe host responses have been documented in a small percentage of tagged narwhals and beluga whales, which require a more invasive attachment method due to the lack of dorsal fin (Heide-Jørgensen et al. 2017, Burek-Huntington et al. 2022). Reported impacts include local infection, decreased body condition, and even death resulting from ascending infection in at least one beluga whale case (McGuire et al. 2021a,b). The cause of re-stranding or death was not associated with the impact from the tagging site in any of the cases presented here, nor have these more severe impacts been reported elsewhere in small cetaceans with dorsal fin attachments. In humans with ear piercings, complications such as minor infection, scarring, and traumatic tearing are reported in 35% of individuals, despite the possibility of post-procedural care and a non-aquatic healing environment (Meltzer 2005).

Nearly half of the animals involved in this study had re-stranding and/or death attributed to stranding-induced trauma and an additional 3 cases also had evidence of this process along with other pre-existing chronic conditions. Stranding-associated trauma is a common necropsy finding in stranded dolphins on Cape Cod, whether satellite tagged or not (IFAW 2023). Strandings have been found to cause a variety of conditions associated with the acute trauma of the event, including shock, myopathy (rhabdomyolysis), multi-organ hemorrhage, and cardiomyopathy (Herráez et al. 2013, Sharp et al. 2014, Sierra et al. 2017). Strandings are inherently stressful events for cetaceans, and while rescue efforts may save the lives of many of these animals, these actions can also provide stressors. IFAW's rescue protocols have made significant advances over the years to reduce the stress of rescue activities on the animals by minimizing handling, noise, and time out of the water. Tagging procedures are short duration (generally a few minutes for ID tags and less than 10 min for satellite tagging), but may still be a source of some stress to the animals. In the USA, tagging prior to release is required by the federal body that issues permits regarding stranding activities (National Oceanographic and Atmospheric Administration). Additionally, tagging provides critical feedback that allows stranding responders to improve care provided to future stranded animals, and thus benefits of tagging likely significantly outweigh the risks.

Comparisons between tag attachment methods from the current study indicate that associated pathology may be less severe with the biopsy application method (used for biopsy identification tags and satellite tags) as opposed to the piercing method. In 2/3 histopathology cases with 2 tag types the histologic changes were similar but more severe at the piercing tag site compared to the satellite tag site. In Case 2, accumulations of serum within affected regions of the epidermis and moderate dermal fibroplasia were noted at the piercing tag site, and in Case 8 a higher level of bacterial colonization was noted at the piercing tag site. Necrosis was also seen more frequently in piercing (43%, 3/7) compared to biopsy tag sites (20%, 2/10). Marked compression and tearing of the epidermis and dermis were only grossly evident in piercing tag sites from this study.

The differences in observed pathology between piercing ID tag and biopsy ID tag application methods suggest the latter may be a better protocol for tag application. With the piercing method, a sharp tipped pin is pushed through the fin, compressing the tissues in the transverse plane. Once in place, compression radiates out from the central pin resulting in increased pressure in the tissues surrounding the pin, potentially resulting in vascular compression or constriction, localized ischemia, and pressure necrosis. Alternatively

with the biopsy-type applications (ID and satellite tag attachment procedure in this study), a core of tissue is removed before or during pin insertion, eliminating the compression of the tissue. Another study found similar favorable results for the biopsy attachment method when the same biopsy identification tags were deployed on rehabilitated seals in the Netherlands, compared to traditional piercing identification tags (van Neer et al. 2020).

Another point of interest is the timeline of healing at the tag sites. Dermal wound healing generally occurs in 3 phases: inflammation (approximately Days 0–5), proliferation (Days 4–12), and tissue remodeling/maturation (Days 17–20 through 12–18 mo) (Schreml et al. 2010). These phases represent a continuum with some overlap between them. The intervals between tagging and re-stranding in this study ranged from 1 to 28 d, with all but one re-stranding 12 d post-tagging or earlier. Therefore, these tag sites would be expected to fall within the inflammatory or proliferative phases of healing. The edema observed and described above was identified 4–5 d (Case 8, piercing ID and biopsy satellite tag sites) and 10 d (Case 2, piercing ID and biopsy satellite tag sites) after tagging, consistent with a potentially delayed inflammatory healing phase. Granulation tissue was observed grossly on Day 12 for Case 9 (biopsy satellite tag site). The only observed macroscopic necrotic lesions were apparent in the piercing tag site of Case 4, 28 d after tagging. This suggests that healing was not complete at this latter time point for this piercing attachment site. This healing delay is expected with a chronically present foreign body experiencing constant drag forces and suggests that healing may not be complete until the tag migrates caudally out of the trailing edge of the dorsal fin or otherwise detaches from the animal. Additionally, the animals used in this study were tagged at stranding, an event that often leads to shock and possibly peripheral vasoconstriction which could result in a prolonged healing process. Therefore, the histopathologic response and healing process of tagging insults in non-stranded animals may not be completely reflected here. Sonne et al. (2012) reported nearly complete marsupialization of epithelial tissue (part of the proliferative healing phase) within the multipin-tag attachment site after 84 d, also representing a potential delay in healing at the tag site in a non-stranded individual. Due to the small sample size and limited duration of tag attachment at the time of post-mortem examination in this current study, additional cases are needed to provide a clear healing timeline for tagging attachment sites.

Vessel-based surveys of piercing identification tag attachment sites in live small cetaceans reported that they appeared fully healed after natural tag loss, leaving only a small notch in the dorsal fin (Irvine et al. 1982, Wells et al. 1998). Another study reported full healing of biopsy tag attachment sites of 2 bottlenose dolphins *Tursiops truncatus* outfitted with single pin satellite tags on the dorsal fin trailing edge (Balmer et al. 2011). Consistent with the findings of Sonne et al. (2012) and Heide-Jørgensen et al. (2017), healing took longer (39 d after natural tag loss) in an animal whose tag showed caudal migration through the dorsal fin, whereas healing had occurred just 8 d after galvanized corrosion-induced tag loss in another animal (Balmer et al. 2011).

IFAW also had 2 cases of *D. delphis* that were tagged, released, and re-stranded 48 d later with no tags present and partially healed notches in their dorsal fins at each prior tag site, indicating complete caudal tag migration (IFAW Database; Fig. 4). IFAW14-147Dd had a biopsy satellite tag and piercing identification tag attached and IFAW14-149Dd had a piercing identification tag attached. The tag sites were partially healed (pallor and slightly raised margins with granulation tissue present) and did not have macroscopic evidence of necrosis or infection. Both animals were deemed healthy again upon re-stranding, with minimal changes to weight and other health parameters, were relocated and released a second time and were not documented to re-strand thereafter. Seven days prior to re-stranding, IFAW14-147Dd's satellite tag had ceased transmission, indicating the likely time of complete caudal migration of the satellite tag through the trailing edge of the fin, at 41 d post-attachment. Satellite tag migration in this case occurred earlier than in reports from more coastal populations of dolphins or from tags with multiple pin attachments (Wells 2013) and prior to the expected timeline of galvanic release of the tag (~60 d). These findings together suggest that efforts should be made to select tags and tag attachment methods that reduce the likelihood of tag migration through the fin by minimizing drag, and using appropriately placed attachment sites and appropriately timed remote detachment methods. When that is not possible, the proportion of the fin affected by tag migration should be minimized by using single pin tags and attaching the tag close to the trailing edge of the dorsal fin.

There were several limitations to this study. The small and opportunistic retrospective sample set included here prevented statistical analysis and limits the degree to which these conclusions can be applied to cetacean tagging broadly. Tissues were also sam-

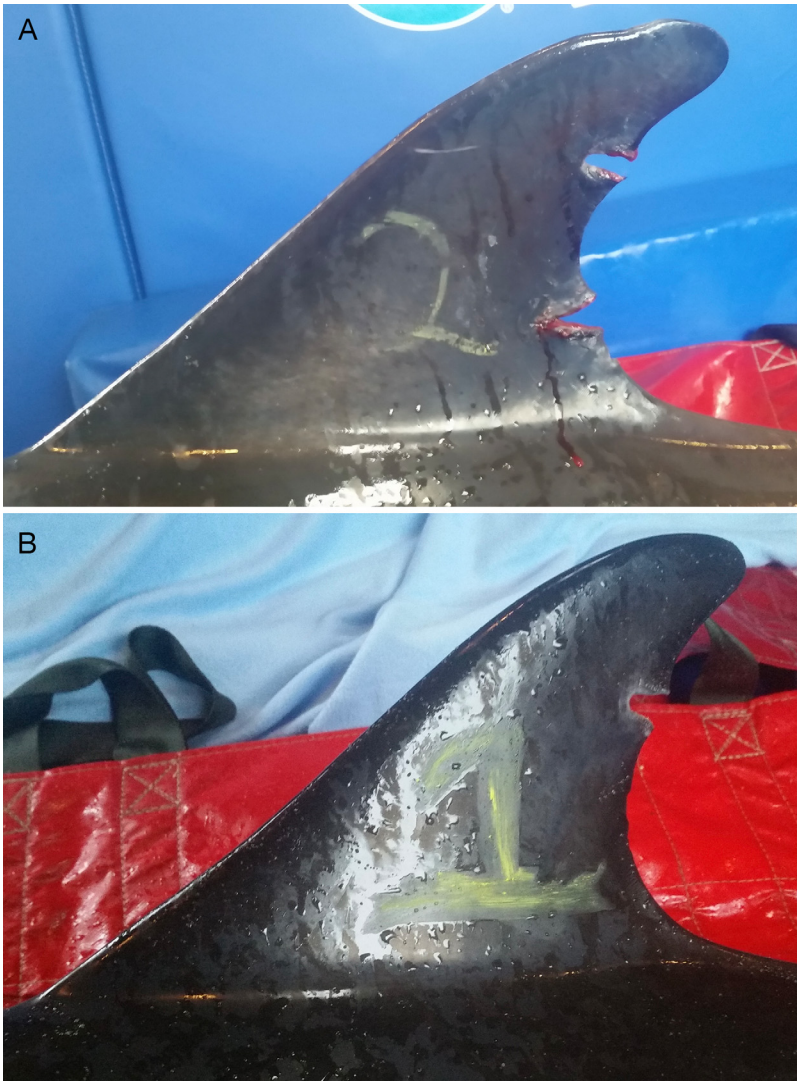

Fig. 4. (A) IFAW14-147Dd 48 d after tag attachment and likely 7 d after complete satellite tag migration, loss, and cessation of tracking data (proximal notch). ID tag (distal notch) also migrated caudally out of the fin within this timeframe. (B) IFAW14-149Dd 48 d after attachment of a piercing identification tag, demonstrating partial healing (pallor and slightly raised margins with granulation tissue present) after tag migration and loss

pled relatively soon after tag placement, limiting understanding of impacts from longer duration tag attachments. However, given the rarity of these cases, this study still represents a valuable number of histopathological samples from tagged delphinids. Additionally, the carcasses in this study presented in varying states of decomposition, from fresh to moderate decomposition at the time of necropsy, leading to possible post-mortem differences in macro- and microscopic appearance of the tag sites. Gross observations were also made by different individuals, resulting in varying descriptions of tag attachment sites. Macroscopic descriptions of the tag sites became more detailed over time as protocols improved, and thus small, expected changes may not have been documented as thoroughly in earlier cases. In the future, having gross observations made by the same trained individual following a standardized tag site sampling protocol that optimizes gross and histopathological visualization of the attachment site would be preferable to ensure inter-case comparisons are robust. Additionally, multiple pathologists read the histopathology slides, and therefore small differences in interpretation may be present within this dataset.

As with any medical procedure, especially those that are relatively new, collecting all possible information regarding the impact of the tag on an animal including time to migration and healing, resulting fin pathology, and associated health implications is essential to inform tag attachment protocols and tag designs in the future. CT scans of tag attachment sites were not available in any of these cases, but may provide additional information regarding tissue integrity, tag remnants or broken attachments, when feasible to perform.

In conclusion, all gross and histopathological findings in this study were consistent with what would be expected from transepidermal tagging and support the previous boat-based survey findings that temporary dorsal fin tags in small cetaceans cause minimal damage and do not impact the general health of the individual. Tagging procedures are necessary for post release monitoring of stranded individuals, as well as to gather data to inform health assessment and release decisions in future cases. Whenever undertaking these procedures, all possible precautions should be taken to minimize the risk of infection at the tagging site. There is some indication that removal of tissue from the tag attachment site by core biopsy may reduce the potential for tag site pathology due to compressive trauma. Further investigations into tag attachment site pathology are warranted to better inform tag selection and attachment protocols to minimize the impact of these procedures on small cetaceans.

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