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Bottlenose dolphin (*Tursiops truncatus*) depredation resulting in larynx strangulation with gill-net parts

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ABSTRACT

Cetacean interactions with fishing gear are reported regularly and most frequently involve incidental capture. However, limited records exist related to depredation resulting in fishing gear ingestion. Here, we present cases of depredation resulting from ingestion of gill-net parts and larynx strangulation documented for the first time in a cetacean species. The bottlenose dolphin (*Tursiops truncatus*) is the only

resident species in the Adriatic Sea, where small-scale commercial and private fisheries use gill nets throughout the year. A total of 120 dead-stranded bottlenose dolphins found along the Croatian coast of the Adriatic Sea were examined from 1990 to March 2008; 12 of them (10%) were affected by larynx strangulation with gill-net parts. The larynx of all affected animals showed at least one of the following pathological changes: edema, mucosal injury, and hypergranulation. In the majority of cases, it was a chronic condition. Larynx strangulations were found only in adult animals and appeared more often in animals with reduced ability to catch free-swimming prey.

Key words: bottlenose dolphin, *Tursiops truncatus*, Adriatic Sea, depredation, gill net, net ingestion, larynx strangulation.

Interaction with fishing gear is an important factor in cetacean pathology. Interactions of cetaceans with fishing gear occur because of their strategy to increase the rate of feeding while decreasing the energy expenditure associated with foraging (Fertl and Leatherwood 1997). The most frequently reported form of interaction with fisheries is incidental capture, for example, entrapment and entanglement in fishing nets, which has a high mortality rate and even impacts the population dynamics of small or localized cetacean populations (Northridge 1984). Although incidental capture usually results in the death of the animal concerned, there are also instances where cetaceans are injured or affected in some way during fishing operations so that their survival probability or reproductive potential is compromised (Northridge 2002). Some cetacean body parts, namely the respiratory, musculoskeletal, and digestive systems are especially exposed to fishing gear interactions. Two cases of fishing gear (fishing hook and lure) ingestion by bottlenose dolphins from Florida were documented by Gorzelany (1998).

Our paper deals with 12 bottlenose dolphins from the Adriatic Sea affected with larynx strangulation by gill-net parts. The position of the larynx in toothed whales makes it vulnerable to foreign bodies, for example, fishing-net parts, during deglutition. The larynx is elongated into a tubular extension, the laryngeal spout, that transverses the digestive tract into the nasal cavity, where it remains in the erect position during deglutition (Fig. 1). This position of the larynx provides a direct conduit for inspired air from the blowhole and nasal cavity to the larynx, trachea, and lungs, while the food is swallowed through wide food channels lateral to the larynx (Reidenberg and Laitman 1987), and not over it as in terrestrial mammals. As larynx strangulation with gill-net parts has not yet been described within the cetacean pathology, our goal is to present pathological findings and hypothesizes on the pathogenesis.

Materials and Methods

As part of a long-term project to investigate marine mammal strandings, 120 bottlenose dolphin (*Tursiops truncatus*) carcasses found in the Croatian part of the Adriatic Sea were examined from 1990 to March 2008. Postmortem examinations included determination of species, sex, body mass, external measurements, and a pathoanatomical dissection according to a standard protocol (based on Kuiken and García Hartmann 1991). The depth of blubber was measured at fixed positions.

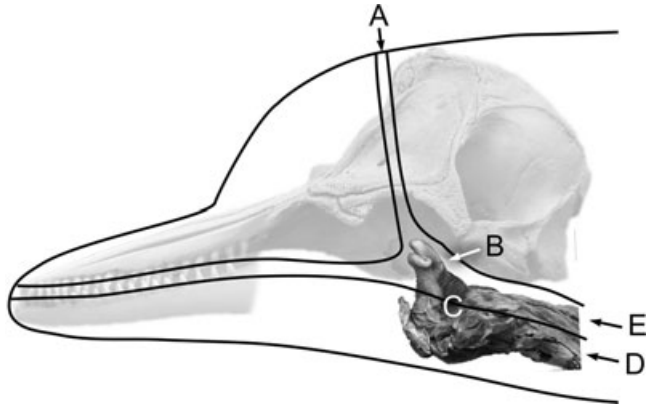

Figure 1. Schematic drawing of the larynx position in the bottlenose dolphin: (A) blowhole, (B) laryngeal spout, (C) larynx, (D) trachea, (E) esophagus.

In animals with signs of larynx strangulation with gill-net parts, the finding was examined macroscopically and photographed; both the larynx and pharynx were dissected. The wet specimens are stored permanently in 4% formalin at the Faculty of Veterinary Medicine, University of Zagreb. Necropsy protocols of all 120 examined bottlenose dolphin carcasses were reviewed and data on animals found with gill-net parts in the stomach were analyzed. Teeth sections were prepared according to Slooten (1991) and the age was estimated by counting growth layer groups (GLGs) according to Hohn *et al.* (1989).

Results

Animals Affected by Larynx Strangulation and/or Ingested Gill-Net Parts

In 12 bottlenose dolphins (10%), the larynx was strangulated with a gill-net part. Four of them also had gill-net parts in their forestomachs. An additional eight animals had gill-net parts in their forestomach, but no signs of larynx strangulation. The gill-net parts in the forestomachs ranged in number from one to 13, and in size from 20 × 20 cm to 80 × 90 cm. A majority of the gill-net parts were made of cotton, with the mesh size ranging from 20 to 40 mm. All animals affected either by larynx strangulation or by ingestion of gill-net parts were older than 7 yr and a majority were older than 17 yr (Fig. 2, Supporting Table S1). The affected animals were found throughout the Croatian coast of the Adriatic Sea (Fig. 3) during the whole year (Supporting Table S1).

Larynx Strangulation

A fishing-net part hanging from the mouth (Fig. 4) was the first indication of larynx strangulation in the examined animals. In two of the affected animals (No. 141 and 170) no net was present. When present, the fishing-net part originated from gill nets made of cotton or nylon with a string thickness of 0.3–0.5 mm and net mesh size of 30 or 40 mm. In some cases the gill-net part was a combination of nylon and

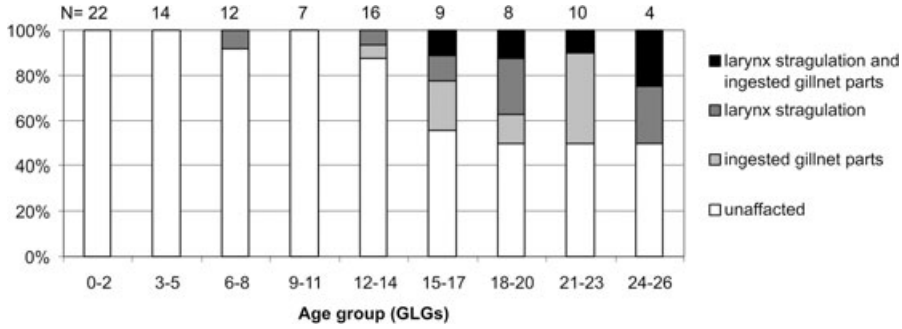

Figure 2. Percentage of bottlenose dolphins affected by larynx strangulation and/or ingested gill-net parts in each age group. Here, *N* represents the total number of examined animals in each age group for whom age determination was possible.

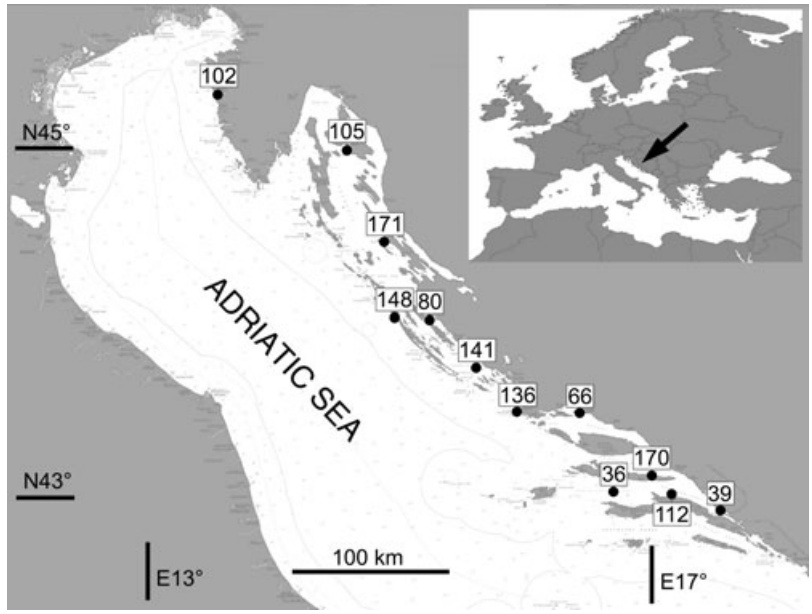

Figure 3. Geographic location of findings of dead bottlenose dolphins with larynx strangulation in the Croatian part of the Adriatic Sea.

cotton, which is often the result of damaged net patching. Multispecies, small-scale commercial and private fisheries use such gill nets set at different depths year round throughout the eastern Adriatic Sea. The gill-net part causing larynx strangulation was usually in the form of an interweaved cord encircling the dorsolateral wall of the laryngeal spout and forming a U. In some cases, the left and right strips of the U were hanging as two separate strips in front of the larynx. More often, these two strips intertwined oral to the laryngeal spout and formed a unique cord with a length of 30 cm to 1 m hanging out of the mouth. The gill-net part encircled the basal

Figure 4. Gill-net part causing larynx strangulation and protruding from the mouth of a bottlenose dolphin.

part of the laryngeal spout, whereas the top of the spout was affected only in dolphin No. 136. The gill-net part caused mucosal injury but was not overgrown and could be removed from the region without any tissue damage. The nylon net meshes were ingrown in the surrounding pharyngeal mucosa only in dolphin No. 36.

The larynx of all affected animals showed at least one of the following pathological changes: edema, mucosal injury, and hypergranulation. The mildest changes (Fig. 5B) were found in dolphins No. 80 and 112. In these animals, the fishing-net part caused a lesion in the form of a shallow (*ca*. 2 mm) semicircular groove, up to 5 mm wide, in the mucosa and submucosa of the dorsal wall at the laryngeal spout base. A strong edema affected the laryngeal spout, especially the top, and the surrounding pharynx. In dolphin No. 102, the edema was accompanied by strong hypergranulation stretching from the injury at the base of the laryngeal spout to its top; the mucosal injury was up to 1.5 cm deep (Fig. 5C).

The most severe lesions were found in half of the affected animals. In these animals, the top of the laryngeal spout was edematous and there was hypergranulation surrounding the mucosal injury. The mucosal injury was in the form of a deep semicircular groove penetrating all mucosal layers with the larynx cartilages protruding at the bottom of the groove (dolphins No. 36, 66, 136) or there was even a dorsolateral opening into the laryngeal lumen (dolphins No. 39, 141, 171) (Fig. 5D). As already stated, in dolphin No. 136 the gill-net part, just one mesh string, was encircling only the top of the laryngeal spout and not the base as in other affected animals. In dolphins No. 105 and 170, the deep semicircular groove penetrated all mucosal layers, but no hypergranulation was present (Fig. 5E).

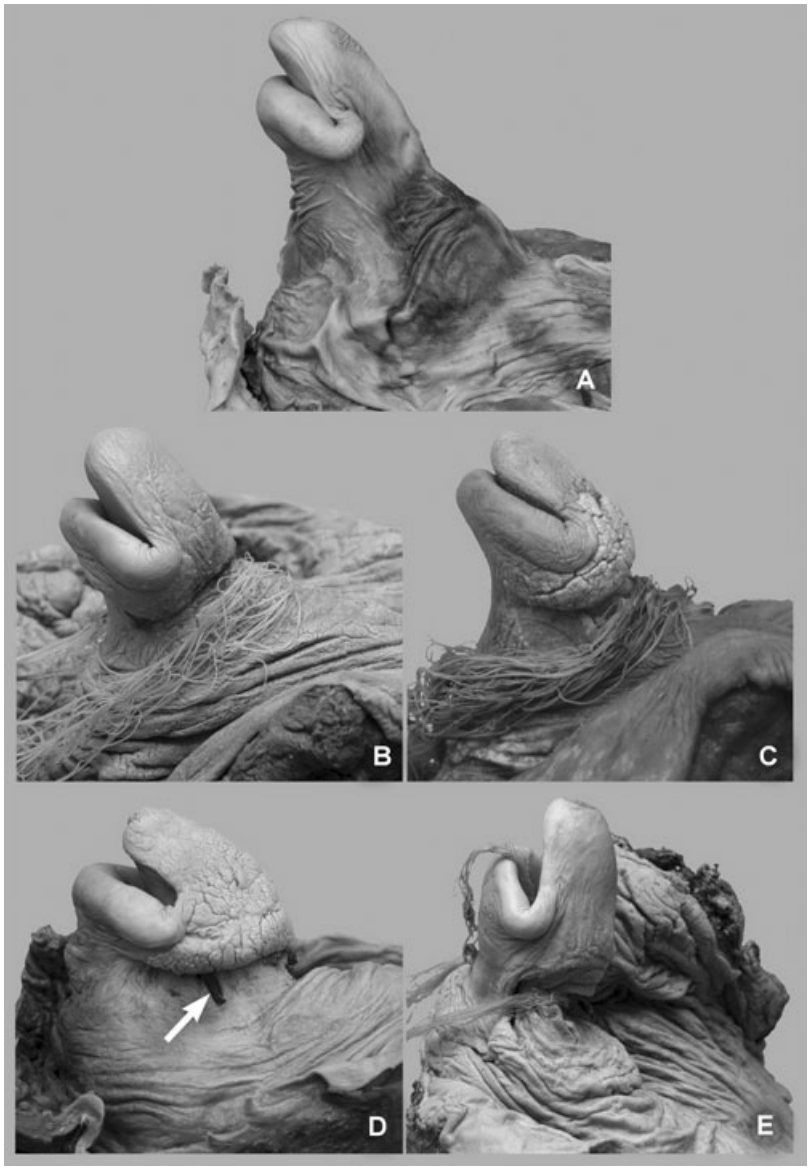

Figure 5. Healthy bottlenose dolphin larynx (A). Different cases of larynx injuries caused by gill-net strangulation: edema, shallow mucosal, and submucosal injury (B); edema, shallow broader mucosal and submucosal injury, and hypergranulation (C); edema, hypergranulation, and arrow showing open laryngeal lumen (D); edema, dorsolaterally open laryngeal lumen, without hypergranulation (E).

Other Pathological Findings in Dolphins Affected by Larynx Strangulations

The other most common pathological conditions were found on lungs. Diffuse pneumonia was determined in three animals (No. 66, 80, 102); while in dolphin

No. 112 a ruptured cavern was found on the right lung causing pyothorax and death. Strong infestation by *Anisakis simplex* was found in two dolphins (No. 80 and 136) followed by heavy forestomach ulceration in dolphin No. 80. Another heavy forestomach and esophageal ulceration was found in dolphin No. 170, but with no evidence of parasites. Arthritis was found in the occipital joint of dolphin No. 80 and in the left shoulder of dolphin No. 141. Other pathological conditions observed only in a single animal are listed in Supporting Table S1. The teeth of six dolphins were heavily worn down; one animal (No. 80) had partly broken and partly missing teeth. Reduced blubber thickness was observed in three dolphins (No. 39, 136, and 170). Although cachectic, dolphin No. 39 had food remains in its forestomach (Supporting Table S1). In dolphin No. 148, the fishing net surrounding the larynx was the only proof of larynx strangulation; other pathological changes could not be determined due to the advanced decomposition of the carcass.

Discussion

The most probable scenario leading to larynx strangulation is that dolphins tear off a part of the gill net while feeding on fish entangled in the fishing nets. Sometimes the torn gill-net part gets swallowed completely together with prey and no larynx strangulation occurs. This is supported by findings of dolphins with gill-net parts in their forestomachs, but without larynx strangulation (Fig. 2). However, the torn gill-net part might only partly pass into the esophagus during the swallowing of the prey while the rest of it hangs through the pharynx and the oral cavity out of the mouth (the hanging part can be as long as 1 m). Such gill-net parts cannot be sucked into the oral cavity and swallowed completely. A partially swallowed gill-net part causes muscular actions of the pharynx inducing regurgitation. This muscular action brings the swallowed part of the gill net out of the esophagus and into the pharynx. The subsequent events are probably crucial for strangulation to occur. When regurgitating, the pharyngeal muscular action might direct the swallowed part into the same lateral food channel where the hanging part lies; then the gill-net part can slip out from the oral cavity with no consequences for the animal. On the other hand, if the swallowed part is directed into the opposite food channel, it will encircle the laryngeal spout and protrude from the mouth. In most cases the two ends of the gill-net part hanging from the mouth will tangle up into a unique cord. During swimming the long cord hanging from the mouth is pulled backward, which makes the part encircling the laryngeal spout move forward and rub the dorsolateral wall. The result of this action is the penetration of the net into the wall of the laryngeal spout causing semicircular injuries. The severity of the pathological changes experienced by the laryngeal spout reflects the time interval between the moment of larynx strangulation and the moment of the death of the animal. In dolphins with mild changes (shallow mucosal injuries with strong edema) the time interval was presumably the shortest. If the time interval is longer, the stimulus of rubbing the dorsolateral wall of the laryngeal spout is present over a longer period causing severe hypergranulation around the mucosal injury. The gill-net part encircling the laryngeal spout cannot be overgrown because it shifts as the animal moves. The shifting gill-net part does not allow the mucosa to regenerate. It penetrates increasingly deeper into the laryngeal wall making it thinner and thinner, until all the layers are penetrated and the lumen of larynx is opened. If the affected animal does not die due to some other cause, it will most probably reach this stage of

larynx strangulation. Nevertheless, its overall health condition is debilitated because the strong edema aggravates respiration while the injuries of the laryngeal spout wall make the respiratory system vulnerable to aspiration of foreign bodies.

In animals with severe injuries but no signs of hypergranulation, the lesions occur rapidly. We presume that this pathological change develops because of an extremely vigorous pulling of the gill-net part hanging from the mouth. It might be a consequence of a dolphin partially swallowing a gill net without tearing a piece of it off in the first place and then trying to free itself with forceful jerks. We presume this kind of lesion causes death very quickly because no signs of injury reparation, that is, hypergranulation, are found. Still, larynx strangulation does not seem to cause sudden death frequently as the majority of the affected animals had chronic larynx strangulation reflected in hypergranulation.

The pathological findings determined in the affected animals are inconclusive regarding the effect of the larynx strangulation on other organ systems. Larynx strangulation might interfere with the dolphin's ability to feed, as three affected animals had reduced blubber thickness (Supporting Table S1). Nonetheless, in most cases, larynx strangulation does not prevent subsequent feeding, as half of affected animals had food remains in their forestomachs and a majority of them were not cachectic.

Interaction of cetaceans with fishing nets as part of their feeding strategy is a well-known behavior. Bottlenose dolphins biting and damaging nets and forming small holes on fish farm cages were observed off Sardinia (Díaz López 2006*a*). We presume that feeding on fish from gill nets is not an inborn behavior in bottlenose dolphins, and that it is instead learned from other conspecifics. This is supported by the estimated age distribution of the affected animals (all animals were older than 7 yr) (Fig. 2). The residency of the animals in the region where such fishing gear is used is probably contributing to a common use of this feeding strategy. Namely, the bottlenose dolphin is the only resident cetacean species in the Adriatic Sea (Gomerčić and Huber 1989, Gomerčić *et al.* 1998, Galov *et al.* 2008) where identifiable bottlenose dolphins also show a degree of residence in certain areas (Bearzi *et al.* 1999, Đuras Gomerčić *et al.* 2003). A study made off the coast of Sardinia confirms that when gill nets are present, there is regular, year-round interaction between bottlenose dolphins and fisheries (Díaz López 2006*b*). Fish entangled in gill nets present a source of concentrated prey all year round and are probably the only feeding source for animals with reduced hunting ability, as a large number of affected animals had problems within the feeding apparatus, for example, worn teeth (see teeth condition, Supporting Table S1).

The examined carcasses of other cetacean species did not show signs of larynx strangulation (Gomerčić *et al*. 2002); therefore, we conclude that larynx strangulation with gill-net parts is a pathology restricted to the bottlenose dolphin species inhabiting coastal areas of eastern Adriatic Sea where small-scale commercial and private fisheries that use gill nets are predominant. Our results also indicate that larynx strangulations are found only in adult animals, that is, animals that acquired the feeding behavior of taking fish from gill nets; and appear more often in animals with reduced ability to catch free-swimming prey.

There are different measures proposed to reduce dolphin interactions with gill nets. Such measures involve reducing fishing seasons or regions (Murray *et al.* 2000), establishing marine protected areas free of gill-net fishing (Dawson and Slooten 1993), and gear modifications (Dawson 1991). All the options for mitigating the

problem of dolphin larynx strangulation should be explored through controlled field tests.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1. Data on bottlenose dolphins from the Adriatic Sea affected by larynx strangulation with gill-net part.