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Hook shedding and post-release fate of deep-hooked European eel

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ABSTRACT

The European eel (*Anguilla anguilla*) is a commercially and recreationally important fishery target species. In the last decades, the eel has experienced dramatic stock declines and has been listed as critically endangered. To reduce fishing mortality, several European countries have closed the fishery or introduced stricter management measures which increase the likelihood of catch-and-release in the recreational fishery. This study investigated hook shedding mechanisms of deep-hooked, line-cut eels via radiography, and quantified hook shedding rates, post-release mortality and sub-lethal effects in captivity. Eels were caught with four different hook treatments, monitored in a tank for 23 weeks, and radiographed 0, 1, 3, 10, 24, 54, 115 and 163 days after capture. After 163 days, total hook shedding rate was significantly higher for smaller hooks (41.2%) compared to larger hooks (0.0%), and increased with fish length. Post-release mortality rates ranged between 27.3% and 50.0% after 23 weeks (not adjusted for handling and holding) and did not differ significantly between hook treatments. The majority of dead eels showed gastric perforations caused by the hooks leading to internal haemorrhaging and the intrusion of digestive fluids into the body cavity inducing lethal degradation and inflammation of vital organs. Anglers are encouraged to minimise bycatch of eel in countries where eel harvest is prohibited. Anglers targeting eel should use selective and appropriate fishing gears, baits and tactics (e.g. very large hooks, immediate hook setting after a bite) to reduce deep hooking and the catch of undersized eels, ultimately promoting the eel's conservation.

1. Introduction

The catadromous European eel (*Anguilla anguilla* L.) is a socio-economically and culturally important commercial and recreational fisheries resource throughout Europe (Bernotas et al., 2016; Dekker and Beaulaton, 2016; Moriarty and Dekker, 1997; Pawson et al., 2007; Ringuet et al., 2002; van der Hammen et al., 2015). However, since the late 1970s, the European eel population has experienced dramatic declines and is currently considered to be outside safe biological limits (Aalto et al., 2016; Dekker, 2003, 2008; Dekker and Beaulaton, 2016; FAO and ICES, 2007). As a result, the European eel has been listed as critically endangered by the International Union for Conservation of Nature (Jacoby and Gollock, 2014) and in Annex II of the Convention on International Trade in Endangered Species (CITES, 2014) to control its trade. Amongst others, climate change, overfishing, pollution, habitat loss as well as an introduced parasite (i.e. *Anguillicoloides crassus*) and diseases are suggested as possible causes (reviewed in Bevacqua et al., 2015; Dekker, 2008; FAO and ICES, 2007; Feunteun, 2002). Since 2007, a Council regulation of the European Union (EU) obligates all European Member States to provide eel management plans for each river basin ensuring at least 40% escapement of the original biomass of mature eels to the sea (relative to undisturbed life conditions [CEC, 2007]).

For many European anglers, eel is still an important target species, and several European studies have shown that recreational eel harvest can exceed commercial eel harvest on a regional scale (Dorow and Arlinghaus, 2011; ICES, 2016; van der Hammen et al., 2015). To reduce fishing mortality, some countries (e.g. United Kingdom, the Netherlands, Sweden and Norway) have prohibited harvest of eel (Ferter et al., 2013; ICES, 2016). Other countries have introduced stricter bag limits or higher minimum size limits (ICES, 2016). Stricter recreational harvest regulations increase the likelihood of regulatory catch-and-release (C&R) which means catching a fish using hook and line, and releasing it alive to the waters where it was caught under the general assumption that it will survive (Arlinghaus et al., 2007). C&R is a widely spread practice and has gained broad acceptance worldwide as fisheries management tool and conservation strategy (reviewed in

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Arlinghaus et al., 2007; Cooke and Schramm, 2007). A study from the Netherlands revealed high release rates up to 72% for eel resulting in 887,000 released eels in the Netherlands alone (van der Hammen et al., 2015), and there is also evidence for high eel release proportions in other European countries (ICES, 2016).

Amongst others, anatomical hooking location, specifically deep hooking, has been identified as dominating factor having lethal and sub-lethal effects for a variety of fish species post release (reviewed in Arlinghaus et al., 2007; Bartholomew and Bohnsack, 2005; Cooke and Wilde, 2007; Hühn and Arlinghaus, 2011; Muoneke and Childress, 1994). Deep hooking is defined as the hook penetrating the oesophagus, stomach, gills, or other vital tissues or organs beyond the mouth cavity (Fobert et al., 2009), and is associated with severe injuries and haemorrhaging. Eel anglers are often faced with deep-hooked fish due to the commonly used fishing method (passive bottom fishing with conventional J-style hooks and small live baits at night) and the foraging behaviour of eels (rapid swallowing of the bait) resulting in a difficult bite detection (Tesch, 2003; MSW, pers. obs.). The question arises what anglers should do when they catch a deep-hooked eel that has to be released (e.g. due to management regulations such as minimum landing sizes). They can either attempt to remove the hook with fingers, pliers or other hook removal devices, or cut the fishing line and leave the hook in place (Fobert et al., 2009). Hook removal from deep-hooked eels is very challenging because of the eel's slim, snake-like body shape, the pronounced mucous layer and the extreme agility (all hindering hook localization and removal), and may lead to severe injuries of the eel (Tesch, 2003; MSW, pers. obs.). Several studies have shown that post-release survival is higher when ingested hooks are left in the fish compared to cases where the hook was removed (e.g. Butcher et al., 2007; Fobert et al., 2009; Grixti et al., 2010; Mason and Hunt, 1967; Tsuboi et al., 2006; Warner, 1979). Moreover, it has been demonstrated that many species are able to shed the embedded hook after cutting the line in the short- to long-term, and that hook degradation occurs due to corrosion processes (reviewed in Hall et al., 2009). Nevertheless, post-release survival and hook shedding rates after cutting the line are highly variable both within and between species, and depend on a variety of factors such as hook style and material, environmental conditions and the functional morphology of the digestive system (Broadhurst et al., 2007; DuBois and Pleski, 2007; Hall et al., 2009; McGrath et al., 2009). Even if survival is high, fish may still suffer sub-lethal effects such as hindered feeding, impaired growth and fitness, behavioural changes (e.g. Aalbers et al., 2004; Hall et al., 2009) or long-term pathological consequences (Borucinska et al., 2002) due to hook retention.

According to some anecdotal information from anglers, eels also seem to be able to shed retained hooks (MSW, pers. comm.). However, to the best of our knowledge, no literature describing either hook shedding, post-release mortality or sub-lethal effects of deep hooking in eels or other Anguilliformes exists (ICES, 2016). Considering the precarious situation of the European eel stock, there is an urgent need for such studies to provide fisheries manager and anglers with better information on the effects of C&R on eel, and with ways to enhance post-release survival and fish welfare to promote the conservation of the European eel. Therefore, this study aimed to (i) describe hook shedding mechanisms including hook corrosion, (ii) quantify hook shedding rates, and (iii) investigate post-release fate (both sub-lethal effects and mortality) in deep-hooked eels.

2. Material and methods

2.1. Study site and fish capture

The experiment was carried out at the Matre Research Station of the Institute of Marine Research (IMR) in Matre, Norway between May and October 2014. Thirty-two eels were caught using rod and line in lake Hillandsvatnet (60°34.495′N, 5°12.565′E), province Hordaland, southwest Norway from the shoreline at night between the 20th and 22nd of May 2014. Surface water temperatures ranged between 9.8 and 15.0 °C during this period. Fishing methods (angling with a fishing float [bobber] or a sinker at the bottom) and tackle (hook, line and bait) representing common eel angling practice were used to simulate representative angling conditions (Tesch, 2003). Either large (size #2, 10.0 mm gap width) or small (size #6, 6.8 mm gap width) common offset baitholder style single hooks (Gamakatsu®, Japan, model LS-3113R) were used which consisted of red-lacquer coated carbon steel and had a barb at the hook point and a baitholder barb on the shank (Fig. 1). This hook model was selected as it represents a hook shape commonly used by European eel anglers (MSW, pers. obs.).

Both hook sizes were used in original configuration (with hook and baitholder barbs present; henceforth called: "barbed") and with the barbs pinched down with handheld pliers (henceforth called: "barbless") resulting in four versions of the same hook model. This treatment was chosen to test if the presence or absence of barbs affect hook shedding rates in deep-hooked eels as the use of barbless hooks would be an easy to apply management measure, but only few studies with contrary findings exist (DuBois and Pleski, 2007; Robert et al., 2012; Stein et al., 2012).

All hooks were attached to a 7.0 kg monofilament leader line, and baited with 1–2 live earthworms (*Eisenia hortensis*). During a bite, each eel was given sufficient time to swallow the bait (1–5 min) to increase the likelihood of deep hooking. After setting the hook, eels were landed immediately and, when deep-hooked (defined as fish hooked beyond the mouth cavity), the line was cut as close as possible to the mouth. Afterwards, each eel was placed individually in a numbered, lockable 10-L bucket filled with fresh lake water. Condition of the fish, occurrence of immediate hook shedding as well as oxygen and water temperature in the buckets were regularly monitored. Holding water was periodically exchanged to ensure an adequate water quality (dissolved oxygen ≥8.0 mg/L, temperature difference to the lakes' surface water temperature ≤ 2.0 °C). Total holding times in the buckets ranged from 3.5 to 9.5 h. Time of capture, hook size and type (barbed or barbless) were recorded for each eel.

2.2. Data collection and holding

At the end of each fishing session, the eels were transported to the Matre Research Station (~50 min transportation time). Upon arrival, all eels were anaesthetized using aqueous solution of 2-Phenoxyethanol (1.5 mL/L), length measured (total length [TL] to the nearest cm), weighed, and individually tagged with passive integrated transponder tags (PIT tag; ID 162–8-PM, EURO I.D., Weilerswist, Germany; dimensions: 2.12 mm Ø × 9 mm length) inserted into the posterior abdominal

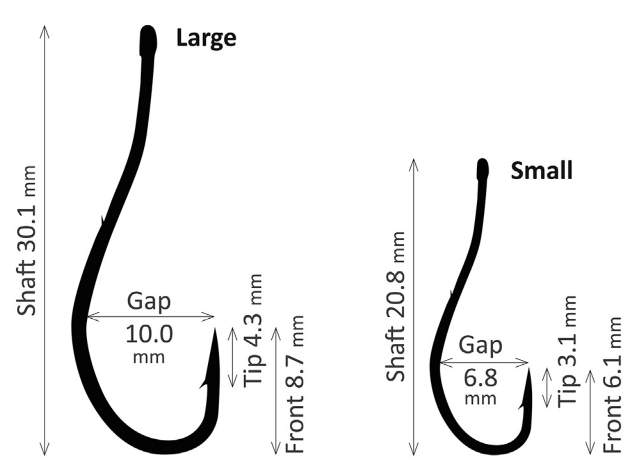

Fig. 1. Schematic drawings and dimensions of the two hooks (large: size #2 and small: size #6) used in the study. Both hook sizes were used in a barbed (as shown in the figure) and a barbless version (barbs pinched down) resulting in a total of four different treatments.