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Mortality induced by drifting longline hooks and branchlines in loggerhead sea turtles, estimated through observation in captivity

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ABSTRACT

1. Drifting longlines are considered a major threat to endangered sea turtle populations worldwide. However, for a number of reasons, the mortality rate of captured turtles is not known with any certainty.

2. Information on 409 loggerhead turtles (*Caretta caretta*), collected during the day-to-day activities of a turtle rescue centre in Lampedusa island, central Mediterranean, in the period 2001–2005 has been analysed.

3. Observations indicate that: (i) drifting longlines are a major cause of mortality for sea turtles in the area; (ii) in addition to the hook, the piece of line attached to it (branchline) can easily cause death if it is long enough and well-anchored; (iii) hooks and branchlines cause death in the short and long term, respectively; (iv) a turtle with a hook in the lower oesophagus/stomach has a very low chance of surviving the combined effect of hook and branchline; (v) the mortality of turtles with a hook in the mouth or higher oesophagus is probably important, though less than that of turtles with a hook in the lower oesophagus/stomach; (vi) in the study fishery, the average mortality of a turtle caught by a drifting longline is probably much higher than 30%.

4. Without specific investigations on the mortality of turtles with hooks in the mouth or higher oeasophagus, which are usually removed, the mortality induced by drifting longlines will remain unknown, preventing a full understanding of the effect on population growth and the real effectiveness of conservation measures such as use of different hooks and fishing depths, and proposals for adequate fishery management measures.

5. The number of turtles captured by drifting longlines should be drastically reduced, and because of the above uncertainty and the socio-economic importance of the fishery sector, an ecosystem-based management scheme should be promoted that is not limited to addressing only the turtle issue.

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INTRODUCTION

Six of the seven extant sea turtle species are listed as Endangered or Critically Endangered in the IUCN Red List of Threatened Species (www.redlist.org). Among a wide range of different human activities which threaten the survival of sea

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turtle populations worldwide, a major threat is mortality consequent to incidental capture by fishing gear. Sea turtles are caught by most types of fishing gear to a greater or lesser degree, and although information is not yet adequate for all types of gear, at least two are responsible for a high number of deaths: bottom trawl (National Research Council, 1990; Lewison and Crowder, 2007) and drifting longline (Lewison *et al*., 2004). The latter gear targets large pelagic fish such as tuna and swordfish, and comprises a main line many kilometres long, to which hundreds of secondary lines (branchlines) are attached, each carrying a baited hook (e.g. squid, mackerel).

Drifting longlines catch more turtles than any other fishing gear (estimated at more than 200 000 loggerhead turtles, *Caretta caretta*, per year worldwide; Lewison *et al*., 2004), but the associated mortality has not been quantified. In contrast with other fishing gears (e.g. bottom trawl and set net) the mortality observed at gear retrieval is very low (e.g. 0–1.3%; Caminas and Valeiras, 2001; Deflorio *et al*., 2005), but the post-release mortality is suspected to be much higher and is a cause of concern (National Marine Fisheries Service, 2001; Lewison *et al*., 2004).

Unfortunately, post-release mortality is very difficult to investigate, with only two studies thus far providing some preliminary estimates. The best information available at present concerns mortality observed in a sample of loggerhead turtles with ingested hooks, kept in captivity (Aguilar *et al*., 1995); however, this study did not provide any further detail (e.g. necropsy verification of the cause of death; hook position in the body; nature of lethal injuries; etc.). The second study satellite-tracked a number of loggerhead turtles released back into the wild with a hook in the oesophagus or deeper (Chaloupka *et al*., 2004; Parker *et al*., 2005), but a general problem of satellite tracking studies is that they confound real mortality and transmitter failure (Chaloupka *et al*., 2004), and do not provide any description of the internal injuries and their consequences.

Furthermore, since in this kind of study hooks are removed and the branchline (the line carrying the hook) is cut short whenever possible, the post-release mortality caused by hooks in those positions or by long branchlines has not been investigated. However, necropsies of stranded turtles (Bjorndal *et al*., 1994; Oros *et al*., 2004) suggest that the branchline may be a mortality factor too. Unfortunately, it cannot be assumed that, as a rule, fishermen remove hooks from the mouth and throat or even cut the branchline short, as researchers do, because these operations would require bringing the turtle onboard, and reducing the time available for fishing.

It is evident that, although the magnitude of the impact of drifting longline fishing on turtles certainly warrants management actions (Lewison *et al*., 2004), the mortality induced by drifting longlines and associated parameters (e.g. mortality time lag; hook position in the body; effects of branchline; organs affected; etc.) is still unknown and this is needed in order to understand the impact of this fishing gear on marine turtle populations, in terms of negative population growth rate and extinction probabilities. Such information is important in informing decisions on the measures needed for the conservation of a species or a population, especially when such decisions may affect a high economic-value sector such as fisheries. The worldwide use of drifting longlines and the total effort (1.4 billion hooks deployed in the year 2000; Lewison *et al*., 2004), warrant a much better assessment of the mortality induced by this fishing gear as a first step in identifying the conservation measures needed.

The aim of the present study is to improve the knowledge on sea turtle mortality induced by drifting longlines, by providing (i) a new estimation of the mortality of turtles with J-shaped hooks deeply ingested and kept under observation in captivity, (ii) a description of mortality factors, and (iii) indications of mortality induced by branchlines.

MATERIALS AND METHODS

In the period 2001–2005 data were collected from 409 loggerhead sea turtles brought to the Sea Turtle Rescue Centre of WWF Italy at Lampedusa Island (Italy), central Mediterranean (42°40′ N; 16°50′ E), by tourists and local authorities who found them stranded along the coast or floating at sea ($n = 64$), and by fishermen who found them caught in drifting longlines ($n = 341$) or other fishing gear ($n = 4$). Observations from 105 turtles provided specific and detailed data (Appendix 1). The mean length of turtles brought to the centre after being caught by drifting longlines was 43.1 cm Curved Carapace Length notch-to-tip (CCLn-t; Bolten, 1999) (SD: 9.2 cm; range: 25–79 cm; $n = 296$).

Turtles caught by drifting longlines were classified according to how they were captured and the position of the hook: Entangled (only by the line, not by the hook); Mouth (M; hook in the mouth); Higher oesophagus (HO; hook partially visible by looking through the mouth); Lower oesophagus or deeper (LOD; hook not visible); External (hook external of the body). The hook was removed whenever possible, while some turtles with hooks in the LOD were kept under observation. Some of these turtles were periodically radiographed in order to detect possible hook movement along the digestive tract (see Hook Position at time 1 and 2, in Appendix 1).

Necropsies were conducted to determine the cause of death of turtles found in different circumstances (see above).

RESULTS

Hook position

The different hook positions found in a sample of 330 turtles caught by drifting longlines are shown in Table 1. The

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Table 1. Hook position in 330 turtles caught by drifting longline and brought to the rescue centre

Hook position	%	*N*
Mouth	36.4	120
Higher oesophagus	29.1	96
Lower oesophagus or deeper	30.9	102
External	3.3	11
Entangled	0.3	1
Total	100.0	330

proportion of turtles with hooks in the M or HO ($n = 216$) and in the LOD ($n = 102$) observed at the time of capture was different from the proportion observed in the sample of 44 turtles found floating or stranded and with a hook in the body (which without treatment would probably have died) (Appendix 1; group A): seven had the hook in the M or HO and the other 37 in the LOD (Fisher Exact Test; $P < 0.01$; $n = 362$).

The proportion of turtles with hooks in the HO ($n = 96$) and in the LOD ($n = 102$) observed at the time of capture was different from the proportion of turtles captured, found floating or stranded with hooks in the HO ($n = 2$) and in the LOD ($n = 16$) that died due to the branchline (Appendix 1; group B) (Fisher Exact Test; $P < 0.01$; $n = 216$).

Effects of ingested hooks and branchlines

Necropsies showed that ingested hooks caused death as a result of either a perforated heart, blood vessels, or the digestive tract (often the stomach). Hook size relative to turtle size may affect the chances of damage; however, in the study sample there was little variability in hook size (Appendix 1). While lesions by hooks usually cause death within a short period of time, branchlines disable digestive functions, leading to starvation and eventually death after a relatively long period. With a relatively long branchline extending to the intestine but firmly anchored by the hook in an anterior position, usually the oesophagus, the peristalsis (muscle contractions that propels food distally) of the intestine around the branchline tightens the line until it severs the intestine or causes intussusception (when one portion of the intestine slides over the next) or both. Accordingly, branchlines that caused death ranged in length from 51.5–540 cm (mean 167; SD: 116; $n = 21$; Appendix 1; group C; turtles captured, found floating or stranded). Of the six turtles that survived, three expelled branchlines 18, 25 and 80 cm long, together with the hooks (Appendix 1; group D; turtles captured or found floating); the other three expelled branchlines 155, 520 and 640 cm long (Appendix 1; group E; turtles found floating), but in these turtles the hook was absent or had been removed.

Mortality and mortality factors

Since the hook position in the body determined the kind of treatment that the turtle received when brought into the rescue centre (hooks were always removed from turtles with a hook in M or HO), mortality could be directly investigated only for the sub-sample of turtles with hooks in the LOD and where the hook was not removed. Among the turtles captured by drifting longlines and brought to the rescue centre, 34 with hooks in the LOD were kept under observation without operating for a variable period of time (0–37 days) (Appendix 1; group F), until they died ($n = 24$) or were released ($n = 10$). Of the 24 turtles that died (Appendix 1; group G), two died because of the branchline, the hook was the cause of death for 21, and probably also for the other one in which the cause of death was not assessed. The hook was probably the cause, as the turtle died the day it arrived (see below regarding survival time). This leads to a mortality rate of $22/34 = 65\%$ due to hooks, among turtles with hooks in the LOD.

Of 32 turtles found floating at sea, stranded or captured by a fishing gear, and with evidence of a previous capture by longline (Appendix 1; group H), 23 (72%) were killed by the branchline, seven (22%) by the hook, one died for reasons unknown but unrelated to the hook, and in one the cause of death was not clear. In particular, 10 out of 12 turtles found with a branchline exiting the cloaca (an indication of branchline in the intestine) and kept under observation (Appendix 1; group I), died; the two that survived had expelled the hook, so that the branchline was not anchored but free to move. Among the whole sample of 45 turtles found stranded or floating and on which a necropsy was undertaken, the above mentioned 32 with evidence of interaction with longline (Appendix 1; group H) are a majority (71%), indicating that longline is the main mortality factor for loggerhead sea turtles in the area.

The mean length of branchlines attached to turtles found floating at sea or stranded was 166 cm (range: 8–640 cm; SD: 161; $n = 40$), an indication of the branchline length left with the turtle under normal fishing operations in the area.

Observed survival time of turtles with hook or branchline

The period between the date of capture and the last date of observation of 42 turtles captured by drifting longlines (Appendix 1; group J) provided an indication of how long turtles survived after ingesting a hook or branchline. Twenty turtles survived with a hook in their body for 5–45 days (mean 20.8) until they either died for other reasons (branchline; $n = 2$), were operated on and released ($n = 8$), or were released with no treatment ($n = 10$). In contrast, the 20 turtles killed by

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hooks died 0–10 days after capture (mean: 1.8 days), and 75% of them died on the first day. Two turtles died on the day of arrival but the cause of death was not assessed by necropsy. Collaborating fishermen reported another nine turtles that died while onboard on the way into harbour and were thrown into the sea. Although the cause of death of these 11 turtles could not be confirmed, it is likely it was due to hook damage and not to the branchline (which requires more time to result in death, see below). If so, this would mean that 84% of turtles killed by hooks died within the first day after capture. These observations indicate that hooks either kill quickly or they don't kill, at least in the medium term (i.e. 5–45 days).

Among the group J turtles, 11 with hooks in the LOD (Appendix 1; group K) were periodically radiographed during the period they remained under observation at the centre. In nine turtles (82%) the hook remained in the same position (six in the stomach, two in the intestine and one in the oesophagus) for 4–32 days after capture. In one turtle the hook had moved posteriorly after 28 days, and in another one it moved posteriorly and was eventually expelled after 22 days.

Because the branchline was cut short whenever possible, only in two turtles captured by drifting longline was it long enough (96–130 cm) to cause death (Appendix 1; group L).

Forty-four turtles with known time lag from arrival at the centre to death or from arrival to release and with evidence of previous capture by longline (on an unknown date) were found floating at sea, stranded or captured by a fishing gear. Five were killed by hooks 1–31 days after being found (mean: 7.8 days) (Appendix 1; group M) and 18 (Appendix 1; group N) were killed by branchlines 0–44 days later (mean: 16 days; SD: 17 days). Twenty-one turtles survived with the hook in place for variable periods of time (Appendix 1; group O): in four turtles the hook (in the oesophagus or mouth) was removed within the first two days after being found, another eight were operated on after 10–20 days and survived, five expelled the hook after 2–124 days (in one turtle the attached branchline had been removed surgically), and four were released after 46–98 days with the hook still inside.

DISCUSSION

Mortality induced by hooks

The higher proportion of hooks in the LOD among turtles found floating or stranded (which, without treatment, would probably have died) than the proportion observed at the time of capture among turtles captured by drifting longlines suggests that hooks in the LOD are more harmful than hooks in the HO. This is supported by comparison with other studies, which reported lower mortality than that observed in this study (65%), probably because they considered as 'deep' those hooks in both the LOD and HO. Aguilar *et al.* (1995) observed 29% mortality among 38 turtles kept under observation in captivity (73–123 days) with a hook deep in the body. They did not clearly describe the hook position; however, they considered 'deep' those hooks whose removal is 'impossible under field circumstances', and so probably correspond to hooks in both the HO and LOD. Chaloupka *et al.* (2004) satellite-tracked turtles released with a deep hook and estimated that 34% of the transmitters stopped transmission, because of either technical problems or turtle death. They defined as 'deep' those hooks ('caudal to the glottis'), corresponding to both categories HO and LOD. It is likely also that there is little difference in hook type; in all the studies they were J- shaped hooks of similar size, although the hooks observed by Chaloupka *et al.* (2004) were probably somewhat smaller (Work and Balazs, 2002).

Among the turtles that died owing to the branchline, the proportion of those with hooks in the HO was lower than the proportion observed at the time of capture, and the most likely explanation for this difference is that, given enough time (branchlines kill turtles in the long term), some hooks in the HO move deeper. However, it should not be assumed that once in deeper positions these hooks induce the same mortality as hooks in the LOD observed in turtles just captured, because conditions are different: the branchline is not fixed to the gear and there are no fishermen to pull it, so that these hooks do not necessarily engage in a second position as they would at capture, and so might even be expelled without harm.

There is no evidence or clues about mortality induced by hooks in the M. However, on the basis of the direct experience of hook removal from the mouth at the rescue centre, it is unlikely that a hook can disengage easily from the mouth in the wild. It is likely that a hook in the mouth could compromise feeding performance, especially if it impeded closure of the mouth. It has been reported that fine-scale movements of mouth closure are involved in olfactive and feeding performances (Hochscheid *et al.*, 2005) and thus a hook in the mouth may induce a non-negligible mortality.

Finally, although hooks appear to kill turtles in a short time in most cases, it is possible that a second and lower mortality peak occurs after periods longer than those observed in this study caused by secondary infections or other problems.

Mortality induced by branchlines and hooks

Present results show that a branchline can easily kill a turtle if two conditions are met: (i) the branchline is long enough to be affected by intestinal peristalsis; and (ii) it is anchored anteriorly (usually through the hook).

What constitutes a lethal branchline length might depend on turtle size. In this study, the shortest branchline that caused death (of a turtle 53 cm CCL) was 51.5 cm long, while Bjorndal

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et al. (1994) reported that one turtle of a different species (*Chelonia mydas*) died due to a branchline of 34 cm.

On the basis of the observed branchline lengths of turtles found floating at sea or stranded (mean 166 cm), and of information obtained directly from fishermen, as well as other studies in south Italy (Guglielmi *et al*., 2000), the common practice of fishermen is to cut the branchline from the deck while the captured turtle is in the water (i.e. from a distance of over 1 m), so leaving most turtles released in this way with branchlines longer than 1 m and thus potentially lethal.

Because branchlines require more time than hooks to kill a turtle, only turtles that survive the hook are subject to the mortality induced by branchlines. Assuming that 65% of turtles with hooks in the LOD die because of the hooks, and that the remaining 35% have a mortality of 82% (the observed proportion of well anchored hooks; see above) owing to the branchline (all these values should be considered as indicative only because of the small sample size), turtles with a hook in the LOD would have little chance of surviving, especially under 'normal' fishing operations (i.e. long branchlines left attached to turtles).

Overall mortality induced by drifting longline

Since hook position in the body may have a considerable effect on mortality, turtles caught by drifting longline cannot be treated as a homogeneous group, and the overall mortality (OM) should be calculated by adding the respective frequencies (f) and mortalities (m) of each hook position (M, HO, LOD): $OM = M_f{*}M_m + HO_f{*}HO_m + LOD_f{*}LOD_m$.

No direct observations are available about mortality induced by the hook alone or about the proportion of well-anchored hooks in turtles with hooks in the M or HO, because these turtles are usually de-hooked by researchers or veterinarians. However, turtles found floating at sea or stranded, but with evidence of a previous capture by longline, do actually represent turtles suffering from hooks and branchlines combined and can give some indirect evidence. Assuming that without treatment these turtles would have probably died, the ratio M-HO/LOD observed in this sample (0.19) can be viewed as the relative importance of the mortality of turtles with the hook in the M-HO and the mortality of those with the hook in the LOD. In other words, M-HO mortality would be 19% of LOD mortality; and if the latter is 94% ($0.65 + 0.35{*}0.82$; see above), M-HO mortality would be 18%. Although these figures and calculations should be regarded just as an exercise, they nevertheless suggest that mortality in the category M-HO is not insignificant but important.

Since present results indicate a very high mortality rate in turtles with hooks in the LOD (representing 30.9% of the sample; Table 1) and a not insignificant mortality in turtles with hooks in other positions (65.4% of the sample), it is likely that for the study area and fishery and for fishermen using 'normal' fishing practices, the average mortality rate of turtles caught by drifting longline is well above 30%.

Implications for conservation and recommendations

The present study represents a first attempt to combine mortality induced by hooks and branchlines, and suggests that the mortality rate of turtles caught by drifting longlines could be higher than previously thought (17–42%; Lewison *et al*., 2004).

Branchlines appear to be a major mortality factor and research into how to reduce the impact of branchlines should be carried out. Four findings are of interest in this respect: (i) the affected organ is the intestine; (ii) in most cases the anterior anchorage of the lethal branchline is cranial to the intestine, so that at least a part of the branchline lays in the stomach; (iii) if not anchored, branchlines can be expelled without harm; (iv) death typically occurs after many days. Therefore, it is possible that a branchline made of a material rapidly degradable by the acidic environment of the turtle's stomach will have enough time to break, thus leaving the part in the intestine free to move and eventually to be expelled, before causing lethal damage.

A high number of deaths caused by interaction with drifting longline in the study area is suggested by (i) the high mortality observed in this study and the high number of turtles caught in the area (Casale *et al.,* in press); and (ii) the high proportion of turtles with evidence of a previous capture by longline observed among necropsies of turtles found stranded or afloat.

Since a high proportion of turtles are caught with a hook in the LOD, which is associated with high mortality due to the hook alone, awareness campaigns and tools (e.g. handling practices and dehooking devices) given to fishermen so that they can cut the branchline short and remove hooks in the M and HO whenever possible, cannot solve the problem (also because such initiatives are limited in coverage), although they are valuable as mitigating measures. Therefore, a substantial reduction in the number of turtles captured is deemed an absolute necessity.

Several measures have recently been proposed to reduce turtle bycatch (see Gilman *et al*., 2006 for a review), among which two are particularly promising. One is to use larger hooks, which are less likely to be swallowed by turtles due to physical constraints of the mouth (Watson *et al*., 2003) and have been proven to be effective in reducing turtle catch rate in the north Atlantic (Watson *et al*., 2005). A second one is to set the hooks deeper in the water column. Loggerhead turtles are thought to spend most of the time at less than 60 m and to dive no deeper than 100 m (Polovina *et al*., 2003). Naturally, these technical modifications should be field-tested in every single

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fishery, in order to assess the effect on the catch of target species.

However, the greatest challenge in tackling the sea turtle bycatch issue is to evolve from a qualitative stage (measures able to reduce the threat by an unquantified extent) to a quantitative stage (measures able to remove the threat) or, in other words, to understand how much turtle bycatch reduction is sufficient. At present, it is plain that any measure, such as a reduction of fishing effort, correct handling procedures onboard, use of larger hooks, and deeper hooks, can reduce the number of turtles being caught or dying. While the overall mortality caused by drifting longlines is not assessed and the effect of this mortality on the growth of the populations affected is not evaluated, the long-term effectiveness of these measures for the conservation of sea turtle populations remains uncertain. With the present state of knowledge, it is possible that some or all of the measures and the scope of their implementation may just mitigate the threat and not remove it. Understanding what catch rate reduction and what fleet coverage are necessary to prevent population decline through these measures, is impossible without knowing the mortality induced by this fishing gear. Furthermore, with no reliable mortality estimation available, decision makers may be reluctant to implement conservation measures with the urgency and scope that is necessary. Ineffective or insufficient measures may even be an obstacle to the implementation of further measures, if they are erroneously considered as sufficient.

This study has reported on part of this mortality and highlighted the complexity of the issue. Until now, accurate assessment of the mortality of turtles with hooks in the M and HO was prevented by a reluctance, for ethical reasons, to monitor the consequences of hooks and branchlines under no-treatment conditions. Given the importance of drifting longline bycatch as a global conservation issue, with an estimated more than 200 000 loggerhead turtles caught annually worldwide (Lewison *et al*., 2004) a good assessment of this mortality could benefit the long-term conservation of sea turtle populations.

Meanwhile, the precautionary approach advocates as much bycatch reduction as possible. Among other reasons, the uncertainty of the impact of drifting longlines on turtle populations makes it unlikely that decisions affecting an important socio-economic sector such as fisheries will be taken for turtle conservation only. The measures easiest to implement are those acceptable by fishermen on a voluntary basis, such as different types of hooks that guarantee at least similar catches of commercial species (Largacha *et al.,* 2005). An integrated approach for an Ecosystem Based Management (EBM) of fisheries, taking account of turtles and of other flagship species, may be more effective in implementing conservation measures that benefit not only sea turtles but the marine ecosystem as a whole. For instance, the central Mediterranean is still a high biodiversity area: implementation of an EBM of fisheries in the area would benefit the general biodiversity and the sea turtles. This is a rather ambitious goal that should involve all the countries fishing in the area: first, Italy and Tunisia, but also Libya and Malta. An international agreement, even if initially limited to certain fisheries or taxa, could facilitate the process.

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APPENDIX 1

Detailed information about 105 turtles observed at the rescue centre. Blank spaces: data not available. Under Hook position, '+' means positions of two different hooks. Under Branchline position, 'Mouth' or 'Cloaca' means that part of the branchline was emerging from the body, with the remaining part in an unknown exact internal location, unless this is specified. Under Operated, 'NY' and 'YN' means that the operation removed only one of two elements: see below the notes on the specific turtles. Abbreviations: DLL, Drifting Longline; M, Mouth, HO, Higher Oesophagus; LOD, Lower Oesophagus or Deeper; BL, Branchline. 'Front', 'Middle', 'Rear': generic position along the turtle's body assessed by radiography.

Notes on specific turtles: 21, died under operation: minimum period; 38, hook in the eye; 55, hook 30 cm to cloaca; 76, different period of observation with internal hook and branchline; 76, 77, hook removed, BL expelled; 79, hook in the mouth removed; 81, hook in the esophagus removed; 86, BL removed, hook expelled; 91, BL expelled; 103, hook in mouth removed, the other one expelled.

Turtle groups (see text): A: found floating or stranded and with a hook in the body. B: died from BL while carrying also a hook in HO or LOD. C: with lethal BL of known length. D: survived with BL of known length expelled with the hook. E: survived with BL of known length expelled, and with hook absent or removed. F: captured DLL with hooks in the LOD. G: captured DLL and died with hooks in the LOD. H: evidence of a previous capture by longline. I: found with a BL exiting the cloaca. J: captured DLL with known observation period. K: captured DLL with hooks in the LOD and periodically radiographed. L: captured DLL and killed by BL. M: with evidence of a previous capture by longline, with known observation interval, and killed by hooks. N: with evidence of a previous capture by longline, with known observation interval, and killed by BL. O: with evidence of a previous capture by longline, with known observation interval, and surviving with a hook.

Turtle	Group (see text)	Finding modality	CCL	Hook position category	Hook position at time 1	Hook position at time 2	Hook length (cm)	Branchline position	Branchline length (cm)	Cause of death	Days of obs.	Final status	Necropsy	Operated
1	C,F,G	Capture DLL	33	LOD	Stomach		7	Intestine	150	Hook/BL		Dead	Y	N
2	F,G	Capture DLL	38.2	LOD	Stomach		7.5		16	Hook		Dead	Y	N
3	F,G,J	Capture DLL	50	LOD	Stomach		7		15	Hook	0	Dead	Y	N
4	F,G,J	Capture DLL	34	LOD	Stomach		7.5		5	Hook	0	Dead	Y	N
5	F,G,J	Capture DLL	34	LOD	Stomach					Hook	1	Dead	Y	N
6	F,G,J	Capture DLL	35.5	LOD	Stomach					Hook	10	Dead	Y	N
7	F,G,J	Capture DLL	35.6	LOD	Stomach		7.5		4	Hook	0	Dead	Y	N
8	F,G,J	Capture DLL	38.5	LOD	Stomach		6.5		4	Hook	0	Dead	Y	N
9	F,G,J	Capture DLL	41.5	LOD	Stomach		7		22	Hook	1	Dead	Y	N
10	F,G,J	Capture DLL	46	LOD	Stomach				30	Hook	1	Dead	Y	N
11	F,G,J	Capture DLL	37	LOD	Stomach				15	Hook	0	Dead	Y	N
12	F,G,J	Capture DLL	40	LOD	Stomach					Hook	5	Dead	Y	N
13	F,G,J	Capture DLL		LOD	Stomach					Hook	1	Dead	Y	N
14	F,G,J	Capture DLL		LOD	Hearth					Hook	1	Dead	Y	N
15	F,G,J	Capture DLL		LOD	Intestine					Hook	1	Dead	Y	N
16	F,G,J	Capture DLL		LOD	Hearth					Hook	0	Dead	Y	N
17	F,G,J	Capture DLL	42	LOD	Stomach					Hook	5	Dead	Y	N
18	F,G,J	Capture DLL	41.3	LOD			7	Not present (Cut)		Hook	0	Dead	Y	N
19	F,G,J	Capture DLL	54.5	LOD	Oesophagus		6.5	Not present (Cut)		Hook	5	Dead	Y	N
20	B,C,F,G,J,K,L	Capture DLL		LOD	Intestine	Intestine		Intestine	130	BL	32	Dead	Y	N
21	B,C,F,G,J,K,L	Capture DLL	47	LOD	'Middle'	Intestine		Intestine	96	BL	12	Dead	Y	N
22	F,G,J	Capture DLL	44	LOD						?	0	Dead	N	N
23	F,G	Capture DLL	42	LOD	Oesophagus		7.5		6	Hook		Dead	Y	N
24	F,J	Capture DLL	38	LOD							31	Alive		N
25	F,J	Capture DLL	44	LOD				Not present (Cut)			37	Alive		N
26	F,J,K	Capture DLL	34.2	LOD	Stomach	Stomach	7				17	Alive		N
27	F,J,K	Capture DLL	53	LOD	Stomach	Stomach	6.5				31	Alive		N
28	F,J,K	Capture DLL	35	LOD	'Front'	"Rear"					28	Alive		N
29	F,G,J,K	Capture DLL	39	LOD	Stomach	Stomach		Not present (Cut)		Hook	4	Dead	Y	N
30	F,J,K	Capture DLL	37	LOD	Stomach	Stomach		Not present (Cut)			15	Alive		N

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31	F,J,K	Capture DLL	43.5	LOD	Stomach	Stomach		Not present (Cut)			15	Alive		N
32	F,J,K	Capture DLL	45	LOD	Oesophagus	Oesophagus		Not present (Cut)			10	Alive		N
33	F,J,K	Capture DLL	43.5	LOD	Stomach	Stomach		Not present (Cut)			28	Alive		N
34	D,F,J,K	Capture DLL	42.3	LOD	'Middle'	Expelled			18		22	Alive		N
35		Capture DLL	31	HO	Oesophagus					Hook		Dead	Y	N
36		Capture DLL	38	HO	Oesophagus					Hook		Dead	Y	N
37	J	Capture DLL	33.5	HO	Oesophagus					Hook	0	Dead	Y	N
38	J	Capture DLL	26	M	Mouth		7.4	Not present (Cut)		Hook	0	Dead	Y	N
39	J	Capture DLL		HO	Oesophagus					?	0	Dead	N	N
40	J	Capture DLL	35	M	Mouth		7				13	Alive		Y
41	J	Capture DLL	39	HO	Oesophagus		7				10	Alive		Y
42	J	Capture DLL	42	HO	Oesophagus		7				5	Alive		Y
43	J	Capture DLL	43	LOD	Stomach		7				19	Alive		Y
44	J	Capture DLL	37	LOD	Stomach		7				19	Alive		Y
45	J	Capture DLL	52.3	LOD	Oesophagus		7.2	Oesophagus	7.5		14	Alive		Y
46	J	Capture DLL	38	LOD	Oesophagus		7	Oesophagus	7		13	Alive		Y
47	J	Capture DLL	48.9	LOD	Stomach		7.3	Stomach	5.5		45	Alive		Y
48	A,H,M	Floating	41	LOD	Aorta					Hook	1	Dead	Y	N
49	A,H,M	Floating	86.5	LOD	Intestine		4.5	Mouth		Hook	2	Dead	Y	N
50	A,H,M	Floating	63.7	LOD	Oesophagus		6.2	Intestine / Cloaca	241	Hook	4	Dead	Y	Y
51	A,H,M	Floating	43.3	LOD	Oesophagus		5.6		8	Hook	1	Dead	Y	N
52	A,H,M	Floating	61.5	LOD	Oesophagus		7.5	Mouth	195	Hook	31	Dead	Y	Y
53	H,N	Floating	51							BL	1	Dead	Y	N
54	H,N	Floating	44.3					Intestine		BL	0	Dead	Y	N
55	A,B,H,N	Floating	64	LOD	Intestine					BL	44	Dead	Y	N
56	A,B,H,N	Floating	59	LOD	Intestine		3.5	Intestine		BL	36	Dead	Y	Y
57	A,B,C,H,N	Floating	53	LOD	Stomach		7	Intestine	51.5	BL	11	Dead	Y	N
58	A,B,C,H,N	Floating	79	LOD	Oesophagus		8.7	Intestine	400	BL	0	Dead	Y	N
59	A,B,C,H,N	Floating	66	LOD	Stomach		7.5	Stomach	68	BL	21	Dead	Y	Y
60	A,B,C,H,N	Floating	47.6	LOD	Oesophagus		5.5	Intestine	128	BL	1	Dead	Y	N
61	A,B,C,H,N	Floating	62	LOD	Oesophagus		8.5	Intestine	251	BL	17	Dead	Y	Y
62	A,B,C,H,N	Floating	52	LOD	Cloaca		8.5	Mouth / Intestine	140	BL	4	Dead	Y	N
63	A,B,C,H,I,N	Floating	65	LOD	Stomach			Cloaca	160	BL	43	Dead	Y	N
64	A,B,C,H,I,N	Floating	76.8	LOD	Oesophagus		8.1	Oesophagus / Cloaca	88	BL	1	Dead	Y	N
65	A,B,C,H,I,N	Floating	47	LOD	Stomach		2.7	Intestine / Cloaca	168	BL	1	Dead	Y	N
66	H,I,N	Floating						Cloaca		BL	3	Dead	Y	N
67	C,H,I,N	Floating	63		Not present			Mouth / Cloaca	230	BL	40	Dead	Y	N
68	C,H,I,N	Floating	52.5				8	Cloaca	162	BL	32	Dead	Y	N
69	A,H	Floating	41.2	LOD	Stomach		7		33	Hook		Dead	Y	N
70	A,H	Floating	55.5	LOD	Oesophagus	Oesophagus	7			?	4	Dead	Y	N
71	A,H	Floating	69.2	LOD	Oesophagus		8.5		57	Not Hook	0	Dead	Y	N
72	A,B,C,H,I	Floating	51.5	LOD	Oesophagus		4.5	Cloaca	231	BL		Dead	Y	N
73	C,H,I	Floating	42		Not present			Mouth / Cloaca	78	BL		Dead	Y	N
74	A,D,I,O	Floating	55	LOD	Stomach	Expelled	9	Cloaca	25		124	Alive		N
75	A,D,I,O	Floating	37	LOD	Oesophagus/ Stomach	Expelled	3.5	Cloaca	80		61	Alive		N
76	A,E,O	Floating	60.2	HO	Oesophagus		7.8	Cloaca	520		14 H; 18 BL	Alive		YN
77	A,E,O	Floating	51	M	Mouth		3.7	Cloaca	640		7	Alive		YN
78	A,O	Floating	70	LOD	Intestine	Intestine					89	Alive		N
79	A,O	Floating	43	M, LOD	Mouth + Stomach	Stomach	8.5; 5.5		40		46	Alive		YN

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Appendix 1 *continued*

Turtle	Group (see text)	Finding modality	CCL	Hook position category	Hook position at time 1	Hook position at time 2	Hook length (cm)	Branchline position	Branchline length (cm)	Cause of death	Days of obs.	Final status	Necropsy	Operated
80	A,O	Floating	40.5	LOD	Intestine						98	Alive		N
81	A,O	Floating	57.6	LOD, ?	Oesophagus + Stomach		2.8; 3.6	Mouth / Cloaca	57.3		16	Alive		Y
82	A,O	Floating	48.5	LOD	Stomach		7.2	Mouth / Intestine	176		20	Alive		Y
83	A,O	Floating	42	LOD	Stomach		7.3	Mouth / Intestine	39		14	Alive		Y
84	A,O	Floating	41	LOD	Oesophagus		5.2	Oesophagus	10		1	Alive		Y
85	A,O	Floating	52	LOD	Oesophagus		6.2	Mouth	30		1	Alive		Y
86	A,O	Floating	52.5	LOD	Stomach	Expelled	8	Mouth	86		18	Alive		NY
87	A,O	Floating	66	LOD	Intestine			Mouth	100		18	Alive		Y
88	A,O	Floating	55	LOD	Stomach		3.5				53	Alive		N
89	A,O	Floating	53.6	LOD	Oesophagus		8.5		293		10	Alive		Y
90	A,O	Floating	50	M	Mouth		6.5		80		0	Alive		Y
91	E	Floating	65		Not present			Intestine	155		26	Alive		N
92	A	Floating	50.2	M	Mouth		6.5		572			Alive		Y
93	A	Floating	46.8	HO	Oesophagus		6.5	Mouth / Stomach	200			Alive		Y
94	A	Floating	37	HO	Oesophagus		7		24			Alive		Y
95	A	Floating	41.1	HO	Oesophagus		3.5		122			Alive		Y
96	A,B,C,H,N	Stranded	61	LOD	Oesophagus		7	Stomach / Intestine	92	BL	0	Dead	Y	N
97	A,B,C,H	Stranded		LOD	Oesophagus				540	BL		Dead	Y	N
98	A,B,C,H,I	Stranded	41	LOD	Oesophagus		3.5	Cloaca	82	BL		Dead	Y	N
99	H	2nd Capture		LOD	Stomach					Hook		Dead	Y	N
100	B,C,H,N	2nd Capture	48.6	HO	Oesophagus	Oesophagus	9	Mouth / Intestine	143	BL	25	Dead	Y	N
101	C,H,I	2nd Capture	62	M	Mouth			Cloaca	125	BL		Dead	Y	N
102	O	2nd Capture	40	LOD	"Rear"	Expelled					22	Alive		N
103	O	2nd Capture	46.5	M, ?	Mouth + Cloaca	Expelled	7; 6.5				2	Alive		N
104	O	2nd Capture	57	HO	Oesophagus		5.2	Oesophagus	22.5		13	Alive		Y
105	O	2nd Capture	52.8	HO	Oesophagus		7.4	Oesophagus	351		1	Alive		Y

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