EFFECTS OF LED ILLUMINATION OF STATIC NETS ON SEA TURTLE BYCATCH AND TARGET CATCH IN THE NORTHERN ADRIATIC SEA

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ABSTRACT

Bycatch in small scale fisheries has been recognized as a significant threat to sea turtles globally in the last two decades. In case of static gears, no bycatch mitigation measures were available apart from spatio-temporal closures. Recent experimental trials showed that visual deterrents, such as static net illumination by LED lights of different wave lengths, are an effective bycatch mitigation measure. We tested conservation potential of green-colored LED lights for reduction of loggerhead sea turtle (*Caretta caretta*) bycatch rates in bottom-set gillnets and trammel nets in the Northern Adriatic Sea, one of the most important neritic foraging habitats for this species in the Mediterranean. In addition, we assessed the effect of illumination on target species catch and value per unit of fishing effort (CPUE and VPUE, respectively). The surveys were carried out during regular fishing activities by onboard observers, in period June – September 2018 and April – August 2019. We monitored 98 gillnet and 161 trammel net pairs, with each net pair consisting of illuminated and control net. A total of 11 loggerhead turtles were bycaught: 6 in illuminated and 5 in control nets, with overall mortality rate of 72.7%. Illumination of trammel nets resulted in reduction of target species CPUE and VPUE (23% and 27%, respectively, $p < 0.001$), while the difference in gillnets showed no significant change. The low sea turtle bycatch rates were in stark contrast to these reported by fisherman and bycatch estimates in the Adriatic, especially as the nets were deployed in areas with high densities of loggerheads. Low number of bycaught loggerhead turtles prevented us from drawing conclusions on the effectiveness of net illumination with green LED lights as a tool for bycatch reduction for this species. Possible ecological drivers behind obtained results will be discussed.

INTRODUCTION

Bycatch, the unintentional take of nontarget species or take of unwanted age or size classes of target species, represent a major threat to numerous taxa (Lewison et al. 2014). In the last two decades bycatch of sea turtles in small scale fisheries has been recognized as a significant threat globally (Alfaro-Shigueto et al. 2010). Among different fishing gears, static nets have been identified as one of the fishing gears of the highest conservation concern across different regional management units and species (Wallace et al. 2011).

Small-scale fisheries represent majority of the Mediterranean fishing fleet (FAO 2016) and might be responsible for the highest number of bycaught sea turtles in the region (Casale 2011). In addition, direct mortality in Mediterranean set net fisheries has been estimated to range from 21 % (Lucchetti et al. 2017) up to 82,6 % (Casale 2011). While different actions were discussed for reducing sea turtle bycatch in set nets (Gillman et al. 2010), recent experimental trials showed that visual deterrents, such as net illumination by LED lights of different wave lengths, are an effective bycatch mitigation measure (Wang et al. 2010; Virgili et al. 2018).

Northern Adriatic Sea is one of the most important neritic foraging habitats for loggerhead sea turtle (*Caretta caretta*) in the Mediterranean with estimated bycatch rates of up to 4900 turtles per year in small-scale set net fisheries (Casale 2011). Assessing effects of net illumination on loggerhead turtle bycatch rates in this fishery is thus essential for conservation of this species. With present study we quantified the effect of net illumination with green LED lights on (i) loggerhead sea turtle bycatch rates and (ii) target species catch and value per unit effort in trammel nets and gillnets in the northern Adriatic.

MATERIALS AND METHODS

We used green-coloured LED lights (Centro Power Model CM-1; Figure 1A) with automatic saltwater switch for net illumination. The lights were placed every 10 m along the footrope (Figure 1B). Each trial consisted of a pair of control and illuminated net, deployed a minimum of 100 m apart to avoid illumination of control nets.
The fisherman used gillnets and trammel nets typical for the Northern Adriatic Region (Matić – Skoko et al. 2017). Gillnets had a single net layer with stretched mesh length measuring minimum 140 mm and with single net pane length of approximately 70 m and height 1.65 m. Trammel nets consisted of three net layers, with stretched mesh length of minimum 80 mm for the inner layer and 320 mm for the outer two layers. A single trammel net pane length was 18 m and height 0.8 m.

The surveys were carried out during regular fishing activities by onboard observers, in period June – September 2018 and April – August 2019. For each pair of control and illuminated net data on total net length, location, depth, visibility, sea surface temperature, deployment start and end time were recorded separately. The catch was divided into target catch (retained for selling), retained catch (for personal use or for baits) and discarded bycatch. Animals were determined to the lowest possible taxonomic level, measured to nearest 0.5 cm and weighted to the nearest 10g. Additionally we measured curved carapace length (CCL) and curved carapace width (CCW) of bycaught sea turtles. Alive turtles were flipper tagged and released while turtles considered being in comatose state were kept on board until recovery and if needed transported to local sea turtle rehabilitation centers.

Standardized Catch Per Unit Effort (CPUE) and Value Per Unit Effort (VPUE) were defined to enable comparisons between gears and net pairs (following Wang et al. 2010; Virgili et al. 2018):

$CPUE_N$ - number of turtles caught per unit of effort [N / (1000m x 12h)]
$CPUE_W$ - weight of target catch per unit of effort [kg / (1000m x 12h)]
VPUE - value of catch per unit of effort [EUR / (1000m x 12h)].

Non-parametric Wilcoxon matched-pairs signed-ranked test was used to compare CPUE and VPUE between pairs of control and illuminated nets.

Figure 1. Illuminated set nets. (**A**) Modified attachment of green Centro Power CM-1 light. (**B**) Onboard observer during LED placement on gillnet footrope. (**C**) Deployment of LED light illuminated trammel net.

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RESULTS AND DISCUSSION

The trials were undertaken in territorial waters of Croatia and Slovenia (Figure 2). We monitored 98 gillnet and 161 trammel net pairs with cumulative total effort comparable for control and illuminated nets for both gear types (Table 1). A total of 11 loggerhead sea turtles (*Caretta caretta*) were bycaught: 6 in illuminated and 5 in control nets, with overall mortality rate of 72.7%. Mean CCL of bycaught turtles was 37.0 ± 7.2 cm We detected no significant change in $CPUE_N$ for sea turtles as a result of net illumination neither in gillnets nor in trammel nets (Table 1). Illumination of trammel nets resulted in statistically significant reduction of target species $CPUE_W$ and VPUE (23% and 27%, respectively, $p < 0.001$), while this difference was not evident for gillnets (Table 1).

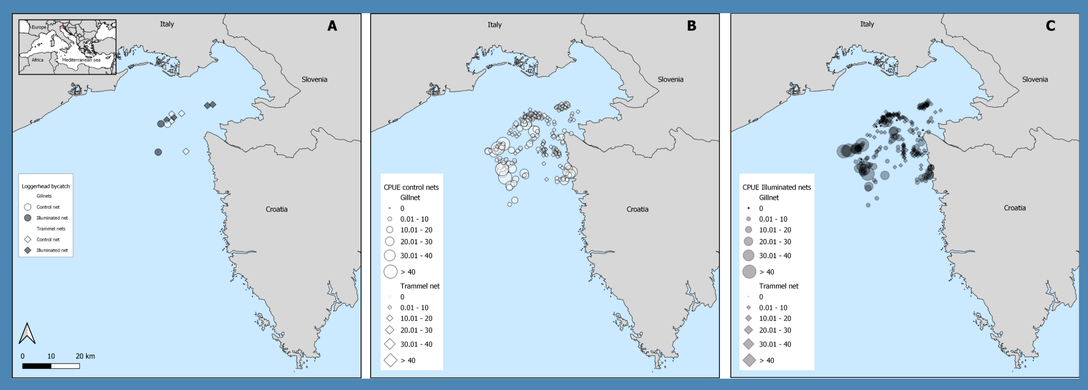

Figure 2. Study area of Northern Adriatic. (**A**) Locations of bycaught loggerhead turtles. Locations and target catch $CPUE_W$ in **(B)** control and (**C**) illuminated nets.

Small-scale set net fisheries in Mediterranean are estimated to unintentionally catch around 23 000/year sea turtles while total take is estimated to be around 14 000/year affecting all life stages (Casale 2011). The area of Northern Adriatic Sea is recognized as one of the most important neritic foraging and developmental habitat for juvenile and adult loggerheads in Mediterranean with predicted surface densities of up to 134 turtles per 100 km^2 (average 20/ km^2; Fortuna et al. 2018). At the same time the north-eastern Adriatic host large small-scale fishing fleet operating with gillnets and trammel nets throughout the year (Matić – Skoko et al. 2017). The overlap of and interaction between these set net fisheries and sea turtles is expected to be more pronounced during warm period of the year (May – October), when animals are more active and more abundant after returning from southern overwintering habitats (Casale et al. 2012). Sea turtle bycatch rates from our study are very low in comparison to these reported by fisherman and bycatch estimates for the Northern Adriatic (Casale 2011; Lucchetti et al. 2017). Our results are especially unexpected as we performed a large number of trials in areas with high densities of loggerheads and during two summer seasons.

Similar to Wang et al. (2010) and Virgili et al. (2018), net illumination resulted in no $CPUE_W$ and VPUE change in gillnets, targeting primarily elasmobranch species, in our case smooth-hound sharks (*Mustelus* sp.). Conversely our results indicate a statistically significant change in $CPUE_W$ and VPUE in trammel nets that are primarily targeting common soles (*Solea solea*). The change in VPUE is also of practical significance, as the fisherman income was reduced by over a quarter in illuminated trammel nets. Loss of income combined with additional costs due to the damage that LED lights caused to the nets lead to indications of reluctance to continue with the trials and will most likely result in non-compliance in case of mandatory use of this bycatch reduction method.

To our knowledge, present study was the first to assess the effectiveness of green LED lights for reduction of loggerhead sea turtle bycatch, especially in trammel nets. However, low number of sampled turtles prevented us from drawing any final statistically supported conclusions on the effectiveness of this method as a tool for bycatch reduction for this species.

Table 1. Summary data of set net illumination trials for gillnets and trammel nets. Values for CPUE and VPUE are expressed as mean ± SD. Statistically significant differences between control and illuminated nets are marked with bold ($p < 0.01$).

		Effort		$CPUE_N$	$CPUE_W$	PPUE
Gear type	Net type	Net pairs	Total (km x 12h)	Loggerheads [N / (km * 12h)]	Target catch [kg / (km * 12h)]	Value of catch [EUR / (km * 12h)]
Gillnet	Control	98	146,58	0,01 ± 0,00	11,79 ± 1,08	74,84 ± 6,89
	Illuminated	98	147,48	0,01 ± 0,00	11,76 ± 1,37	73,16 ± 7,98
Trammel	Control	161	176,66	0,02 ± 0,00	**5,02 ± 0,23**	**72,38 ± 4,87**
	Illuminated	161	175,17	0,02 ± 0,00	**3,85 ± 0,20**	**52,87 ± 3,62**

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