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Sea turtle strandings, sightings and accidental catch along the Croatian Adriatic coast

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Abstract

The northern Adriatic Sea has long been known as the foraging and developmental habitat of loggerhead sea turtles. Previous literature on stranded, floating, sighted, and accidentally caught sea turtles is fragmentary and mainly obtained from this shallower northern part. This work presents data on 272 records of stranded, floating, sighted and accidentally captured turtles within the entire Croatian Adriatic. The data was collected through the national stranding network for strictly protected marine species run by the Croatian Agency for the Environment and Nature during a six-year period (2010-2015). We focused on analysing spatial and temporal observations, age structure, and reporting sources. The collected morphometric data revealed that most measured *C. caretta* (85%) were immature individuals found stranded and floating at sea. These observations were location-dependent with a tendency towards the shallow northern areas (≤200 m). Most of the stranded individuals were severely decomposed preventing the determination of possible mortality causes. Most non-decomposed individuals had fishery- or boat-inflicted mechanical injuries confirming fishing activities and boat collisions as threats to young *C. caretta* individuals in the Croatian Adriatic Sea. Results also revealed an important contribution of local people in reporting the *C. caretta* strandings and sightings whereas most accidentally caught individuals were reported by unknown sources. Altogether, the data presented in this paper indicate possibilities for improving the ongoing sea turtle monitoring and conservation activities along the entire Croatian Adriatic coast.

Keywords: East Adriatic Sea; *Caretta caretta*; spatial observations; temporal observations; age structure; reporting sources.

Introduction

Among the seven species of sea turtles in existence, three appear in the Mediterranean Sea (Casale *et al.*, 2018) and subsequently the eastern Adriatic Sea (Lazar & Tvrtković, 1995). These are the Loggerhead turtle (*Caretta caretta* Linnaeus, 1758), the Green turtle (*Chelonia mydas* Linnaeus, 1758) and the Leatherback turtle (*Dermochelys coriacea* Vandelli, 1761) (Arnold & Burton, 1985; Godley *et al.*, 1998; Casale *et al.*, 2018). Among them, the Loggerhead turtle is the most frequently encountered and the most widely distributed species in the Mediterranean (Margaritoulis *et al.*, 2003). The IUCN (International Union for Conservation of Nature) Red List of Threatened Species lists both *C. caretta* and *D. coriacea* as vulnerable and *C. mydas* as endangered (Seminoff, 2004; Wallace *et al.*, 2013a; Casale & Tucker, 2017). Although *Caretta caretta* is considered of least concern in the Mediterranean, it is regarded vulnerable species in Croatia (Jelić *et al.*, 2012; Casale, 2015) and has been included in most international wildlife conservation treaties (Eckert *et al.*, 2000).

The Adriatic Sea has been identified as one of the most important areas for sea turtles, particularly for *C. caretta*, within the Mediterranean (Casale *et al.*, 2003; Lazar *et al.*, 2004; Casale & Margaritoulis, 2010). Along with the Gulf of Gabes in Tunisia, it is one of the most notable shallow regions in the Mediterranean basin characterized by rich benthic communities (Gamulin-Brida, 1967; Casale & Margaritoulis, 2010). Also, this region is one of the key neritic feeding habitats for *C. caretta* individuals in the Mediterranean (Lazar & Tvrtković, 2003; Casale *et al.*, 2018). Intensive fishing activity in the Mediterranean and subsequently the Adriatic Sea is the main cause of sea turtle (*C. caretta*) mortality, followed by boat collisions (Lazar & Tvrtković, 1995; Gerosa & Casale, 1999; Casale *et al.*, 2010; Lucchetti & Sala, 2010; Turkozan *et al.*, 2013; Wallace *et al.*, 2013b; Lucchetti *et*

al., 2017a, 2017b, 2019; Virgili *et al.*, 2018; Vasapollo *et al.*, 2019). Thus far, such events were quantified along the north and western part of the Adriatic, whereas similar cases were only mentioned to have occurred along the Croatian coast (Casale *et al.*, 2010, 2018). Previous sea turtle research activities within the Croatian Adriatic were mainly conducted in the north and have largely focused on investigating fishery bycatch as the primary anthropogenic threat to sea turtles (Casale *et al.*, 2018). In addition, valuable studies using sea turtle strandings to drive data-based conservation efforts were mainly conducted in the western Adriatic (Casale *et al.*, 2010; Lucchetti *et al.*, 2017a, 2018) and other parts of the Mediterranean (Tomas *et al.*, 2008; Turkozan *et al.*, 2013). Thus, in this study, we bring missing information on sea turtle (primarily *C. caretta*) strandings, sightings and accidental catch for both the northern and southern Croatian Adriatic. This paper is first to analyse and present data on stranded, sighted and accidentally caught *C. caretta* individuals along the entire Croatian Adriatic coast gathered by the Croatian Agency for the Environment and Nature during a six-year period through the national stranding network for strictly protected marine species. The aim of this study is to highlight possibilities for improving the current sea turtle monitoring and conservation activities along the Croatian Adriatic coast by providing basic data on *C. caretta* observations such as: 1) type of observation, 2) their spatial and temporal distribution, 3) estimated age structure of measured individuals, 4) general health condition, and 5) sources that contributed to their reporting.

Materials and Methods

Data collection

The data presented in this study was collected within the area of the Croatian Adriatic Sea by the Croatian Agency for the Environment and Nature during a six-year period (2010-2015) with the help of numerous associates involved in the national stranding network for strictly protected marine species run by the Agency. The species identification for all 272 recorded sea turtle individuals was done by veterinarians and researchers (see Acknowledgements). The general condition of all stranded, floating, and by-caught turtles was examined externally. The date and time of observation, geographical position, and additionally the release date for the recovered turtles were recorded.

When possible, the injured turtles received veterinarian help before they were sent to the Sea Turtle Rescue Centre in city of Pula (Croatia). Because the turtles were often found in a severely decomposed state, only five complete necropsies could be conducted. All parts of fishing gear observed during the examination were recorded. Because of the distance and inaccessibility of the locations or the lack of transport and unavailability of professional personnel, some individuals were left at sea or sank to its bottom. Turtles without apparent health issues were released immediately, or a few hours or days after the veterinarian's approval.

Sea turtle categories were defined as those found dead or injured at the coast (stranded) and those found dead or injured at sea (floating; not found in fishing gear). Sighted individuals were those observed in the sea by locals, tourists, veterinarians and researchers without apparent injuries, whereas those individuals caught by the fishers using fishing gear (*i.e.* trawl nets, gillnets, and longlines) were considered accidentally caught.

Study area

In our analysis, the Croatian Adriatic Sea was provisionally divided into the shallow northern (≤200 m) and deep southern (200-1200 m) area. The northern area thus included the counties of Istria, Primorje-Gorski Kotar, Lika-Senj and Zadar, whereas the southern area included the counties of Šibenik-Knin, Split-Dalmatia, and Dubrovnik-Neretva. The two provisional areas were divided by a green line presented in Figure 1. For comparative purposes, we also used the oceanographic division of the Adriatic Sea on three major sub-basins (northern, central and southern; Fig. 1, black lines) as previously described in Casale & Margaritoulis (2010). Geographical coordinates of all locations were taken with a Garmin eTrex GPS 60CSx or approximated using Google Earth® software. Georeferences were recorded using the WGS 1984 (World Geodetic System 1984; EPSG: 4326) geographic coordinate system. The location and distribution maps of the study area were made using ArcGIS (ESRI 10.2). For map creation, we used a HTRS96 LCC (EPSG: 3766) projected coordinate system.

Morphometric measurements and age estimation

Morphometric measurements could be taken only for 167 *C. caretta* individuals. The curved carapace length (CCL) of *C. caretta* was measured from the nuchal scute to the tip of the last marginal scute (supracaudal) with a measuring tape. Even if the size is not accurate enough to define the maturity of the turtle, because of the variation between regions and even within the same population, it may give insight into the overall age population structure. Thus, we considered individuals of *C. caretta* to be immature with a CCL <70cm (Margaritoulis *et al.*, 2003; Casale *et al.*, 2005). Because of the absence of accurate skeletochronological data for the measured *C. caretta* individuals from the sample size, we relied on the von Bertalanffy' s growth function parameters estimated for *C. caretta* individuals found in the central Mediterranean using the age-at-size method (Casale *et al.*, 2011). To avoid bias in estimating the individuals with the largest CCL (100 cm), we excluded them in our age estimation analysis.

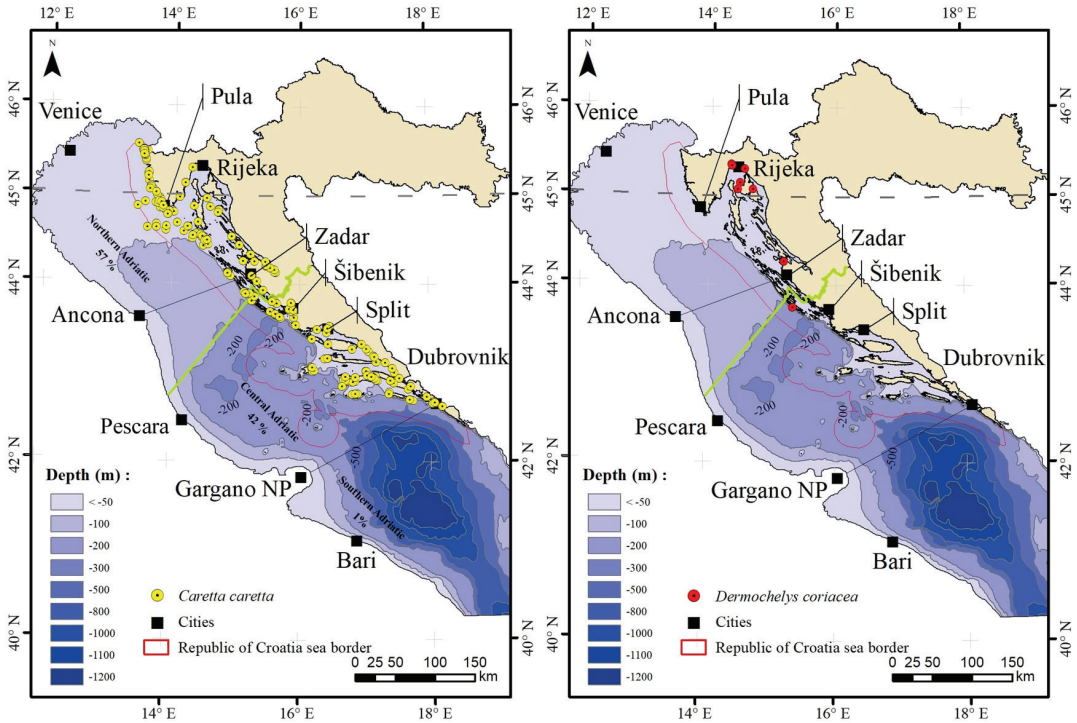

Fig. 1: Spatial distribution of sea turtle (A: *C. caretta*; B: *D. coriacea*) observations along the Croatian Adriatic coast. The green line separates records in the shallow northern (≤200 m) and deep southern (200-1200 m) Adriatic. (A, B) Black lines (Ancona-Zadar and Gargano National Park-Dubrovnik) show the oceanographic division of the Adriatic on three major sub-basins (northern, central and southern) with the respective percentages of sea turtle discoveries shown in A.

Statistical analysis

A non-parametric Mann-Whitney U test was used to analyse the *C. caretta* CCL data recorded in different areas of the Croatian Adriatic Sea (*vide supra*). Statistica® software (Dell Inc. (2016) version 13.2 software) was used to analyse and graphically present data regarding sea turtle observations.

Results

Sea turtle observations along the Croatian Adriatic coast

During the six-year period of data collection, a total of 272 sea turtle individuals were recorded along the entire Croatian Adriatic coast. Sea turtles were mainly identified as *C. caretta* 95.6% (N=260), whereas *D. coriacea* represented 2.9% (N=8) of the observations along the Croatian Adriatic coast (Fig. 1A and B). The exact species of the remaining 1.5% (N=4) turtles observed in the same area could not be determined (Table 1). Of the recorded *C. caretta* individuals, 142 (62%) were found stranded (of which 83.3% were dead), 81 (35.4%) were found floating at sea (of which 45.7% were dead), while the remaining 6 (2.6%) were found at an unrecorded location (of which 66.7% were dead).

The other remaining *C. caretta* individuals were either sighted (N=14; none of which were dead) or accidentally caught by fishers (N=17; of which 17.6% were dead). Most of the accidental catches were caused by unspecified fishing nets (N=8; 47%), fewer individuals were caught by trawlers (N=5; 29%), whereas the lowest number was caught by gillnets (N=2; 12%) and longlines (N=2; 12%).

Table 1. Annual record of observed sea turtle individuals between 2010 and 2015 along the Croatian Adriatic coast.

Species	Year						
	2010	2011	2012	2013	2014	2015	TOTAL
C. caretta	34	20	30	50	73	53	260
D. coriacea	0	3	0	0	5	0	8
Undetermined	-	-	3	-	1	-	4
TOTAL	34	23	33	50	79	53	272

Spatial and temporal distribution

During the monitoring period, *C. caretta* individuals were observed along the entire Croatian coastline. In total, most of the observations (N=159; 61%) were made in the northern area of the Croatian Adriatic Sea. The remaining 101 (39%) observations of the same species were made in the southern area (Fig. 1A). According to the oceanographic division of the Adriatic on three major sub-basins (northern, central and southern), the highest number of *C. caretta* observations was located in the northern

sub-basin (N=148; 57%). A lower number (N=110; 42%) of observations was located within the central sub-basin, whereas the lowest number (N=2; 1%) was observed in the third southern sub-basin (Fig. 1A).

The numbers of observed *C. caretta* within the entire Croatian Adriatic area varied annually between 20 (2011) and 73 (2014). On average, 43.3±7.80 standard error, hereafter, of *C. caretta* individuals per year were recorded along the entire Croatian Adriatic coast (Table 1). Generally, the highest numbers of stranded turtles were recorded in autumn and winter in both the northern and southern Croatian Adriatic, hereafter north and south (north>south). However, while a higher number of stranded turtles was recorded in the north during autumn (>winter), the opposite was recorded in the south (autumn<winter). Floating individuals were recorded mainly in spring and summer in the north and in summer and autumn in the south. Most *C. caretta* sightings and accidental catch in the north were recorded in summer. In the south, all sightings were recorded in spring and summer and all accidentally caught individuals were recorded in autumn (Fig. 2).

Records of both stranded (N=51 *vs*. 42) and floating (N=34 *vs*. 21) *C. caretta* individuals were higher in the north (*vs*. south). When compared to records of floating turtles, more individuals were found stranded in both the north and south (*vide supra*). More dead individuals were also recorded in the stranded *vs*. floating category in both the north (42 vs. 10) and south (33 *vs*. 12). More live *C. caretta* individuals were recorded in the floating (*vs*. stranded) category in the north (24 *vs*. 9) whereas in the south the numbers of live turtles in these categories were equal (9 *vs*. 9). Accidental catch of *C. caretta* individuals in the north was mostly caused by trawlers (N=5; 42%), followed by unspecified fishing nets (N=4; 33%) and gillnets (N=2; N=17%) while longline-related turtle bycatch was recorded only once (8%). In the southern area, the accidental catch of *C. caretta* individuals was primarily caused by unspecified fishing nets (N=4; 80%) and once by longlines (N=1; 20%).

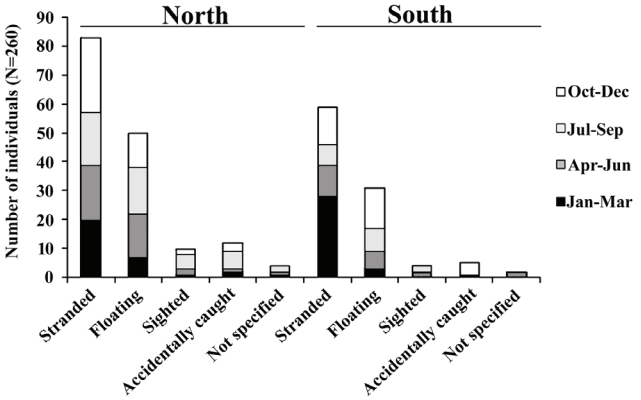

Fig. 2: Seasonal distribution of all records according to finding modality.

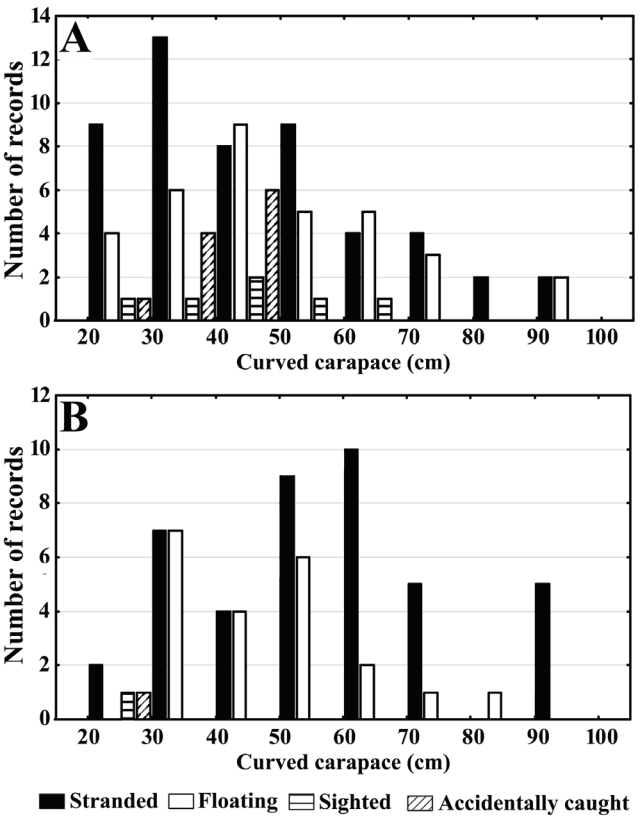

Fig. 3: Size distribution of measured *C. caretta* individuals (N=167) according to different categories (stranded, floating, sighted and accidentally caught) observed in the northern (A) and southern (B) Croatian Adriatic.

Size distribution and age structure estimation

From a total of 260 observed *C. caretta* individuals, the curved carapace length (CCL) of 167 individuals was measured. The CCL of these individuals ranged between 21 and 100 cm with an average length of 52.35±1.5 cm. In general, *C. caretta* individuals recorded in the north were significantly smaller (49.51±1.87 cm vs. 56.81±2.42 cm) than in the south (Mann-Whitney U test; p=0.013; N=167). This spatial difference in size was significant among turtles in the stranded (Mann-Whitney U test; p=0.008; N=93) but not in the floating category (Fig. 3).

Dead turtles (58.4±2.14 cm) were generally larger than the live ones (43.8±1.49 cm) (Mann-Whitney U test; p=0.000003; N=167). Although this size difference was seen both in the stranded and floating turtles, the largest difference was present in the floating category (61.8 cm and 44.9 cm in dead and alive turtles, respectively; N=55). Regarding the spatial distribution, the biggest size difference between dead and alive stranded turtles was observed in the south (64.4 cm and 47.9 cm, respectively; N= 42) whereas the biggest size difference for floating turtles was observed in the north (67.3 cm and 45.5 cm CCL in dead and alive, respectively; N=34).

Immature individuals with CCL ≤70 cm represented 85% (N=142) of the total number of measured *C. caretta* turtles. Individuals with CCL ≤70 cm were estimated to be between 2.9 and 17.6 years of age. Of those, 52.8% were found stranded, 33.8% were found floating at sea, 8.4% were accidentally caught and 5% were sighted. Adult individuals (N=25) were mostly found dead strand-

ed at the coast (72%) or dead floating at sea (24%) whereas only 4% was found injured floating at sea.

General condition of the observed individuals

From the total number of 78 *C. caretta* individuals found injured but alive only two (2.6%) were immediately released because of transport problems, 46 (59%) animals were released after veterinary treatment and recovery, 6 (7.7%) died before receiving adequate veterinary treatment and 14 (17.9%) died after treatment. Because of a lack of follow-up data, we do not have information regarding the remaining 10 (12.8%) injured *C. caretta* individuals. In total, injuries were characterized for only 10 (13%) injured turtles of which 70% were from fishing equipment and 30% were from boat strikes.

The cause of death for the majority of *C. caretta* individuals (N=143; 111 found stranded and 32 found floating at sea) remains undetermined because of their advanced decomposition state. The remaining 36 individuals that were found dead or died before or after the veterinary treatment had visible boat-related and/or fishing equipment-related injuries (Table 2). In total, from these dead *C. caretta* individuals, 18 had visible mechanical injuries due to boat collisions,10 had suffered injuries from fishing hooks and fishing nylon, 5 suffered from net strangulation (unspecified fishing net), two were caught on gillnets and longlines, and one died in a fire accident while stationed in the veterinary clinic. From the total of 5 conducted necropsies on dead *C. caretta* individuals, three showed evidence of fishing material (longline hooks and fishing nylon) in their gastrointestinal tract.

Reporting sources

Local inhabitants reported 48.6% (N=72) of all *C. caretta* stranding records while 23.6% (N=35) was reported by employees of national parks and public institutions. An array of different sources such as tourists, fishers, researchers, veterinarians and coast guard reported 11.5% (N=17) of stranding records, whereas the remaining 16.2% (N=24) were reported by unknown sources.

Regarding *C. caretta* individuals found floating at sea, local inhabitants reported 34.6% (N=28) while 12.3% (N=10) was reported by national parks and public institution employees. Tourists, fishers, non-governmental organisations and veterinarians reported 14.8% (N=12) of findings in this category, whereas the remaining 38.3% (N=31) of turtles were reported by unknown sources.

The majority of *C. caretta* sightings (N=10; 71.4%) were equally reported by locals and unknown sources while the remaining 28.6% (N=4) were equally reported by divers, fishers, national parks and public institutions, and researchers.

The highest number of accidentally caught *C. caretta* individuals were reported by unknown sources (N=10; 58.8%), fewer were reported by fishers (N=3; 17.6%) and locals (N=2; 11.8%), and the lowest number by veterinarians (N=1; 5.9%), and national parks and public institutions (N=1; 5.9%).

Discussion

The data analysed in this study confirms previously published findings that *C. caretta* is the most frequently observed species along the entire Croatian Adriatic coast. Furthermore, it corroborates previous findings indicating *D. coriacea* as the second most observed species in this area (Lazar et al., 2008a; Casale *et al.*, 2018). Similarly to previous reports, the monitoring data suggest the presence of largely immature *C. caretta* individuals and supports previous claims about the (Croatian) Adriatic Sea as an important developmental area for this species (Lazar & Tvrtković, 1995; Affronte & Scaravelli, 2001; Casale *et al.*, 2018). The data also indicate a presence of significantly smaller individuals in the north (*vs*. south), which is in line with previous reports showing recruitment of the northern Adriatic by juveniles (Affronte & Scaravelli, 2001; Lazar *et al.*, 2003, 2008b; Casale *et al.*, 2018).

Table 2. External injuries of *C. caretta* individuals found dead or injured that died before/after veterinary treatment.

Condition	Category	Injuries					
		Boat strikes	Unspecified fishing net	Gillnet	Longline	Fishing hooks and nylon	Fire accident
Dead	Floating	5	2	/	1	/	/
	Stranded	10	1	/	/	6	/
Injured	Floating	2	2	1	/	1	/
	Stranded	1	/	/	/	3	1
TOTAL		18	5	1	1	10	1

A difference in the relative proportion of seasonal observations of stranded turtles between the north and south is comparative to that observed between the north and south in the western Adriatic (Casale *et al.*, 2010). In other words, most stranded turtles recorded in the southern Adriatic were found during winter whereas in the northern Adriatic most stranded turtles were recorded in spring-summer-autumn. This higher number of stranded turtles in winter in the south may reflect the migration of turtles to these warmer areas during the colder winter period or the dynamics of certain anthropogenic factors as was previously suggested for both the eastern and western Adriatic (Lazar *et al.*, 2003; Casale *et al.*, 2010, 2012). However, even though the data on stranded turtles were collected along the entire Croatian Adriatic coast, reliable comparative data regarding the potential causative factors are missing. Thus, to clarify the reasons behind the seasonal stranding dynamics, future monitoring activities in the Croatian Adriatic should take into consideration acquiring comparative seasonal and spatial data on two major anthropogenic threats for sea turtles recognized in the Mediterranean and Adriatic: fishing bycatch (by different fishing equipment) and marine traffic (Caminas, 2004; Lazar *et al.*, 2006; Casale *et al.*, 2007; Lewison & Crowder, 2007; Lucchetti & Sala, 2010; Casale, 2011; Levy *et al.*, 2015; Lucchetti *et al.,* 2017a*,* 2017b). Nevertheless, the records confirm the existence of bycatch by trawlers, gillnets and longlines within the entire Croatian Adriatic Sea. It indicates the northern Croatian Adriatic as the area with the highest number of bycatch records and subsequently the highest proportion of dead turtles (trawlers>unspecified nets >gillnets). These findings are somewhat in line with the conservative estimations of trawler- and gillnet-related bycatch (trawlers>gillnets) given in previous studies for the northern Adriatic area (Lazar & Tvrtković, 1995; Casale *et al.*, 2004, 2010; Lucchetti *et al.,* 2017a). A high level of mortality from trawls in the north is further supported by a generally high number of stranded and a high proportion of dead turtles found there (Casale *et al.*, 2010). In contrast, an interview-based approach estimated a higher mortality for set nets (gillnets) vs. trawl nets (Lucchetti *et al*., 2017a). However, this may be the result of the different, interview-based, approach used to collect bycatch data in that study. In addition, a generally low number of recorded bycatch events within the 6-year monitoring period in combination with a high proportion of undetermined causes of injuries and mortality among the stranded and floating *C. caretta* may have influenced the relations between the mentioned bycatch types in this study. Moreover, a generally low number of accidental catch reports, of which most were from unknown sources, indicate insufficient motivation among fishers for contacting the responsible authorities. Thus, because fishers are active throughout the year, future monitoring and conservation strategies should focus on establishing a credible "data-exchange platform" with fishers so as to acquire more comprehensive and reliable data on turtle bycatch along the entire Croatian Adriatic coast.

In addition to fishery bycatch in the Adriatic, boat collisions seem to be the second major threat for frequently occurring *C. caretta* species (Lazar & Tvrtković, 1995; Casale *et al.*, 2010; Lucchetti *et al.,* 2017a*,* 2017b*,* 2018). Despite a generally low number of recorded injuries, the data presented in this study revealed the presence of severe mechanical injuries caused by marine vessels. Previous studies in the region showed boat collisions to be the second most common cause of mortality (after fishing) in the northern and western Adriatic (Casale *et al.*, 2010). However, because we cannot exclude the possibility that boat strikes happened to some turtles while floating at sea (*i.e.* when released after injury by fishing equipment or after suffocation in fishing nets), the numbers presented here suggest the need to give special attention to the evidence of boat collisions while examining both live and dead turtles in future monitoring activities.

Thus, future sea turtle monitoring activities in the Croatian Adriatic should aim to collect more detailed spatial and temporal data on fishing activities (bycatch; detailed fishing gear separation) and marine traffic (separation by traffic type and its intensity), and improve the exchange of information with local fishers (setting up a reliable data exchange system). Also, detailed data on injuries of stranded, floating, and accidentally caught (dead and alive) turtles should be gathered so as to better assess the possible mortality causes in both the north and south of the Croatian Adriatic.

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References

Affronte, M., Scaravelli, D., 2001. Analyses of stranded sea turtles in the north-western Adriatic Sea. *Zoology in the Middle East*, 24, 101-108.

Arnold, E.N., Burton, J.A., 1985. A field guide to the reptiles and amphibians of Britain and Europe. Collins, London, 272 pp.

Caminas, J.A., 2004. Sea turtles of the Mediterranean Sea: population dynamics, sources of mortality and relative importance of fisheries impacts. FAO Fisheries Report, No 738 (Supplement), 27 pp.

Casale, P., 2011. Sea turtle by-catch in the Mediterranean. *Fish and Fisheries*, 12, 299-316.

Casale, P., 2015. *Caretta caretta* (Mediterranean subpopulation). The IUCN Red List of Threatened Species 2015: e.T83644804A83646294 http://dx.doi.org/10.2305/ IUCN.UK.2015-4.RLTS.T83644804A83646294.en. (Accessed 15 June 2017).

Casale, P., Margaritoulis, D., 2010. Sea turtles in the Mediterranean: Distribution, threats and conservation priorities. Gland, Switzerland: IUCN, 294 pp.

Casale, P., Tucker, A.D., 2017. *Caretta caretta* (amended version of 2015 assessment*). The IUCN Red List of Threatened Species 2017: e.T3897A119333622* https://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T3897A119333622.en. (Accessed 3 June 2020).

Casale, P., Nicolosi, P., Freggi, D., Turchetto, M., Argano, R., 2003. Leatherback turtles (*Dermochelys coriacea)* in Italy and in the Mediterranean basin. *Herpetological Journal*, 13, 135-139.

Casale, P., Laurent, L., De Metrio, G., 2004. Incidental capture of marine turtles by the Italian trawl fishery in the north Adriatic Sea. *Biological Conservation*, 119, 287-295.

Casale, P., Freggi, D., Basso, R., Argano, R., 2005. Size at male maturity, sexing methods and adult sex ratio in loggerhead turtles *(Caretta caretta)* from Italian waters investigated through tail measurements. *Herpetological Journal*, 15, 145-148.

Casale, P., Cattarino, L., Freggi, D., Rocco, M., Argano, R., 2007. Incidental catch of marine turtles by Italian trawlers and longliners in the central Mediterranean. *Aquatic Conservation*, 17, 686-701.

Casale, P., Affronte, M., Insacco, G., Freggi, D., Vallini, C. *et al.*, 2010. Sea turtle strandings reveal high anthropogenic mortality in Italian waters. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20, 611-620.

Casale, P., Conte, N., Freggi, D., Cioni, C., Argano, R., 2011. Age and growth determination by skeletochronology in loggerhead sea turtles (*Caretta caretta*) from the Mediterranean Sea. *Scientia Marina*, 75, 197-203.

Casale, P., Affronte, M., Scaravelli, D., Lazar, B., Vallini, C. *et al.*, 2012. Foraging grounds, movement patterns and habitat connectivity of juvenile loggerhead turtles (*Caretta caretta*) tracked from the Adriatic Sea. *Marine Biology*, 159, 1527-1535.

Casale, P., Broderick, A.C., Camiñas, J.A., Cardona, L., Carreras, C. *et al.*, 2018. Mediterranean sea turtles: current knowledge and priorities for conservation and research. *Endangered Species Research*, 36, 229-267.

Dell Inc., 2016. Version 13.2 software Dell Inc., Tulsa, OK, USA.

Eckert, K.L., Bjorndal, K.A., Abreu-Groboisand, F.A., Donelly, M., 2000. *Tecnicas de Investigacion y Manejo para la Conservacion de las Tortugas Marinas*. Grupo Especialista en Tortugas Marinas UICN/CSE Publicacion, No 4, 260 pp.

ESRI (Environmental Systems Resource Institute), 2013. ArcGIS 10.2. ESRI, Redlands, California, USA.

Gamulin-Brida, H., 1967. The benthic fauna of the Adriatic Sea. *Oceanography and Marine Biology–an Annual Review*, 5, 535-568.

Gerosa, G., Casale, P., 1999. *Interaction of Marine Turtles with Fisheries in the Mediterranean*. UNEP Regional Activity Centre for Specially Protected Areas Report: Mediterranean Action Plan, 59 pp.

Godley, B.J., Gucu, A.C., Broderick, A.C., Furness, R.W., Solomon, S.E., 1998. Interaction between marine turtles and artisanal fisheries in the eastern Mediterranean: a probable cause for concern? *Zoology in the Middle East*, 16, 49-64.

Jelić, D., Kuljerić, M., Koren, T., Treer, D., Šalamon, D. *et al.*, 2012. *Crvena knjiga vodozemaca i gmazova Hrvatske*. Državni zavod za zaštitu prirode, Zagreb, 232 pp.

Lazar, B.,Tvrtković, N., 1995. Marine turtles in the eastern part of the Adriatic Sea: preliminary research. *Natura Croatica*, 4, 59-74.

Lazar, B., Tvrtković, N., 2003. Corroboration of the critical habitat hypothesis for the loggerhead sea turtle *Caretta caretta* in the eastern Adriatic Sea. p. 165-169. In: *Proceedings of the First Mediterranean Conference on Marine Turtles*. Margaritoulis, D., Demetropoulos, A. (Eds). Barcelona Convention–Bern Convention–Bonn Convention (CMS).

Lazar, B., Borboroglu, P.G., Tvrtković, N., Žiža, V., 2003. Temporal and spatial distribution of the loggerhead sea turtle, *Caretta caretta*, in the eastern Adriatic Sea: a seasonal migration pathway? p. 283-284. In: *Twenty-Second Annual Symposium on Sea Turtle Biology and Conservation*. Seminoff, J.A. (Eds). NOAA Technical Memorandum NMFS-SEFSC-503 USA.

Lazar, B., Margaritoulis, D., Tvrtković, N., 2004. Tag recoveries of the loggerhead sea turtle, *Caretta caretta*, in the eastern Adriatic Sea: implications for conservation. *Journal of the Marine Biological Association of the United Kingdom*, 84, 475-480.

Lazar, B., Žiža, V., Tvrtković, N., 2006. Interactions of gillnet fishery with loggerhead sea turtles *Caretta caretta* in the northern Adriatic Sea. p. 252-253. In: *Twenty-Sixth Annual Symposium on Sea Turtle Biology and Conservation, Crete, 3-8 April 2006*. International Sea Turtle Society, Athens.

Lazar, B., Lipej, L., Holcer, D., Onofri, V., Žiža, V. *et al.*, 2008a. New data on the occurrence of leatherback turtles *Dermochelys coriacea* in the eastern Adriatic Sea. *Vie Milieu*, 58, 237-241.

Lazar, B., Gračan, R., Zavodnik, D., Tvrtković, N., 2008b. Feeding ecology of "pelagic" loggerhead turtles, *Caretta caretta*, in the northern Adriatic Sea: proof of an early ontogenic habitat shift. p. 93-93. In: Proceedings of the Twenty-Fifth Symposium on Sea Turtle Biology and Conservation. Kalb, H., Rohde, A.S., Gayheart, K., Shanker, K. (Eds). NOAA Technical Memorandum NMFS-SEFSC, USA.

Levy, Y., Frid, O.,Weinbergerb, A., Sadeb, R., Adam, Y. *et al.*, 2015. A small fishery with a high impact on sea turtle populations in the eastern Mediterranean. *Zoology in the Middle East*, 61, 300-317.

Lewison, R.L., Crowder, L. B., 2007. Putting longline bycatch of sea turtles into perspective. *Conservation Biology*, 21, 79-86.

Lucchetti, A., Sala, A., 2010. An overview of loggerhead sea turtle (*Caretta caretta*) bycatch and technical mitigation measures in the Mediterranean Sea. *Reviews in Fish Biology and Fisheries*, 20, 141-161.

Lucchetti, A., Vasapollo, C., Virgili, M., 2017a. An interview-based approach to assess sea turtle bycatch in Italian waters. *PeerJ*, 5, e3151.

Lucchetti, A., Vasapollo, C., Virgili, M., 2017b. Sea turtle

bycatch in the Adriatic Sea set net fisheries and possible hot-spot identification. *Aquatic Conservation Marine and Freshwater Ecosystems,* 27, 1176-1185.

Lucchetti, A., Angelini, V., Furii, G., Pari, S., Vasapollo, C., Virgili, M., 2018. Evidence of loggerhead seaturtle (*Caretta caretta*, Linnaeus, 1758) injuries caused by Rapido (beam) trawling in the Mediterranean. *Herpetological Journal*, 28, 134-136.

Lucchetti, A., Bargione, G., Petetta, A., Vasapollo, C., Virgili, M., 2019. Reducing Sea Turtle Bycatch in the Mediterranean Mixed Demersal Fisheries. *Frontiers in Marine Science*, 6, 387.

Margaritoulis, D., Argano, R., Baran, I., Bentivegna, F., Bradai, M.N. *et al.*, 2003. Loggerhead turtles in the Mediterranean: present knowledge and conservation perspectives. p. 175-198. In: *Biology and Conservation of Loggerhead Sea Turtles*. Bolten, A.B., Witherington, B.E. (Eds). Smithsonian Books, Washington, DC.

Seminoff, J.A., 2004. *Chelonia mydas*. The IUCN Red List of Threatened Species 2004: e.T4615A11037468.https://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T4615A11037468.en. (Accessed 3 June 2020).

Tomas, J., Gozalbes, P., Raga, J.A., Godley, B.J., 2008. Bycatch of loggerhead sea turtles: insights from 14 years of stranding data. *Endangered Species Research*, 5, 161-169.

Turkozan, O., Ozdilek, S.Y., Ergene, S., Ucar, A.H. *et al.*, 2013. Strandings of loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles along the eastern Mediterranean coast of Turkey. *Herpetological Journal*, 23, 11-15.

Vasapollo, C., Virgili, M., Petetta, A., Bargione, G., Sala, A., Lucchetti, A., 2019. Bottom trawl catch comparison in the Mediterranean Sea: Flexible Turtle Excluder Device (TED) vs traditional gear. *PLoS ONE*, 14 (2), e0216023.

Virgili, M., Vasapollo, C., Lucchetti, A., 2018. Can ultraviolet illumination reduce sea turtle bycatch in Mediterranean set net fisheries? *Fisheries Research*, 199, 1-7.

Wallace, B.P., Tiwari, M., Girondot, M. 2013a. *Dermochelys coriacea*. The IUCN Red List of Threatened Species 2013: e.T6494A43526147. https://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T6494A43526147.en. (Accessed 3 June 2020).

Wallace, B.P., Kot, C.Y., DiMatteo, A.D., Lee, T., Crowder, L.B. *et al.*, 2013b. Impacts of fisheries bycatch on marine turtle populations worldwide: toward conservation and research priorities. *Ecosphere*, 4, 1-49.