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APPARENT INCREASING IMPORTANCE OF ADRIATIC SEA AS A DEVELOPMENTAL HABITAT FOR MEDITERRANEAN GREEN SEA TURTLES (*CHELONIA MYDAS*)

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In the Mediterranean, the green sea turtle (*Chelonia mydas*) has exhibited increase in the number of nests over the past two decades. While the Eastern Mediterranean is recognized as a high use area, scarce observations of green turtles in Adriatic Sea suggested only low-level utilization of this area. This study presents new findings of green sea turtles in the Adriatic Sea and analyses the importance of the region for the species. In combination with published records, we present 75 findings of the species in the Adriatic including eight new records. The number of records is generally low but shows an intriguing ten-fold increase since 2000. This may be a result of three confounding factors: (i) positive population trend at main nesting sites in Mediterranean; (ii) increased institutional capacity for sea turtle research and conservation in the past two decades, and (iii) raising sea temperatures. Documented increases in the sea surface temperatures may have established suitable and recurring thermal corridors along Ionian-Adriatic developmental pathway and provided environmental cues for immigration of juvenile green turtles into the Adriatic. As the abundance of the species will likely increase in the future, research and conservation efforts will be needed to avoid the Adriatic Sea becoming a sink habitat for the Mediterranean green turtle population.

Key words: marine turtles, distribution, Mediterranean Sea, climate change, sea warming, thermal corridors

Jančič, M., Salvemini, P., Holcer, D., Piroli, V., Haxhiu, I. & Lazar, B.: Porast važnosti Jadranskog mora kao razvojnog staništa zelenih želvi (*Chelonia mydas*). Nat. Croat., Vol. 31, No. 2, 225-240, Zagreb, 2022.

Tijekom protekla dva desetljeća populacije zelene želve (*Chelonia mydas*) u Sredozemnom moru pokazu pozitivan trend u broju gnijezda. Iako su vode istočnog Sredozemlja prepoznate kao kritična staništa ove vrste, mali broj dokumentiranih nalaza u Jadranskom moru ukazivao je na sporadični značaj Jadrana kao njenog morskog staništa. Ovim radom predstavljamo nove nalaze zelenih želvi u

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Jadranskom moru, dajemo pregled vremenske dinamike svih potvrđenih dosadašnjih nalaza te analiziramo značaj akvatorija Jadrana za ovu vrstu. U radu prikazujemo 75 nalaza zelene želve u Jadranu uključujući osam novih. Broj dokumentiranih nalaza općenito je nizak, ali pokazuje zanimljiv deseterostruki porast od 2000. godine do danas. Porast u broju nalaza vjerojatan je rezultat djelovanja tri čimbenika: (i) pozitivnog trenda populacija na glavnim gnjezdištima u Sredozemlju; (ii) povećanog institucionalnog kapaciteta za istraživanje i očuvanje morskih kornjača u Jadranu tijekom posljednja dva desetljeća te (iii) povećanje temperature mora. Dokumentirana povećanja površinskih temperatura mora možebitno su uspostavila odgovarajuće i ponavljajuće toplinske koridore duž jonsko-jadranskog razvojnog migracijskog puta koji služe kao ekološki okidači imigracija juvenilnih zelenih želvi u Jadran. Budući da će se brojnost ove vrste vjerojatno nastaviti povećavati, potrebno je povećati napore usmjerene na istraživanja njene prostorne dinamike i zaštitu kako bi se izbjeglo da Jadransko more postane ponorno stanište za sredozemnu populaciju zelene želve.

Ključne riječi: morske kornjače, rasprostranjenost, Sredozemno more, klimatske promjene, zagrijavanje mora, toplinski koridori

INTRODUCTION

The green sea turtle, *Chelonia mydas* (Linnaeus, 1758), is a thermophilic, circumglobally distributed species that inhabits tropical, subtropical and, to a lesser extent, temperate waters (Seminoff *et al*., 2015), which is globally listed as an endangered species by IUCN (Seminoff, 2004). It exhibits the oceanic-neritic developmental pattern, characterized by an early juvenile phase occurring in the oceanic zone and latter shift to near-shore neritic waters (Bolten, 2003). The shift in habitat use during ontogeny is followed by shifts in diet, from epipelagic omnivorous or carnivorous feeding strategy of the oceanic juveniles to dominantly herbivorous diet of the neritic stage turtles, dependent on the availability of local plant communities and, to some extent, by foraging preferences of the species (Bjorndal, 1997; Cardona *et al*., 2010; Seminoff *et al*., 2015).

In the Mediterranean Sea, green turtle populations form an independent regional management unit (Wallace *et al*., 2010), with 13 major rookeries located in Turkey, Cyprus and Syria accounting on average for > 97% nests laid per year (reviewed by Casale *et al*., 2018). No regional IUCN assessment is currently available for Mediterranean green turtle regional management unit, but comparison of average nest counts at 7 nesting sites between pre-1999 and post-2000 periods indicated an overall positive trend, with 47.1% increase in nest numbers (Casale *et al*., 2018). Much less is known about at-sea biology of green turtles in the region. The eastern Mediterranean, particularly the Levantine basin, is recognized as a high use area for pelagic juveniles (Casale *et al*., 2018). However, the presence of small juveniles in the Ionian Sea (Lakonikos Bay, Greece; Margaritoulis & Panagopoulou, 2010) and in the southern Adriatic Sea (Lazar *et al*., 2004; Haxhiu, 2010) suggests that juvenile green turtles may utilise wider oceanic habitats between their natal sites and the Adriatic (Casale *et al*., 2018). Major neritic foraging areas have been identified along the continental shelf of north Africa and Levantine shelf of Turkey, Syria and Israel (Stokes *et al*., 2015; Casale *et al*., 2018).

Thermal biology plays a major role in ecology and distribution of sea turtles (Spotila *et al*., 1997; McMahon & Hays, 2006; Báez *et al*., 2011), hence climate change is expected to affect all of their life stages; impacting reproduction, causing shifts in latitudinal ranges and changes in foraging success (Patrício *et al*., 2021). The warming of Mediterranean basin exceeds the global average (Cramer *et al*., 2018) and we have already witnessed changes in reproductive patterns of regional sea turtle populations in the recent years that included shifts in timing of nesting season (Mazaris *et al*., 2013;

Patel *et al*., 2016) and increase in nesting activity of loggerhead turtle (*Caretta caretta*) in the western Mediterranean (Maffucci *et al*., 2016; Hochscheid *et al*., 2022). The first loggerhead turtle nests have been recently documented in southern Adriatic Sea (Albania; Piroli & Haxhiu, 2020a) and in the northern Adriatic, in the Venice lagoon (Italy) in 2021 (Giuffrida, 2021), representing the northernmost documented nesting location of this species worldwide. Similarly, individual green turtle females have been observed nesting for the first time in Greece (Crete, in 2007 and 2019; Margaritoulis & Panagopoulou, 2010; ARCHELON, unpublished data), Tunisia (Ben Ismail *et al*., 2022) and Libya (2021; A. Saied, *pers. comm*).

The majority of shifts related to climate change impacts on sea turtles are documented for their terrestrial life history phase (Patrício *et al*., 2021). However, both sea turtle species reproducing in the Mediterranean, loggerhead and green turtle, exhibit population increase and increased hatchling production (Casale *et al*., 2018), which, coupled with warming of the Mediterranean Sea, is also expected to result in shifts in marine habitat use (Chatzimentor *et al*., 2021). In this paper we (i) present new records and critically review existing data on green sea turtles in the Adriatic Sea, and (ii) analyse possible importance of the region as a developmental and foraging habitat for the species in light of climate change.

MATERIALS AND METHODS

We report findings of green turtles in the Adriatic Sea based upon new data obtained from fishers and sea turtle stranding networks and collected from citizen science applications. Where possible, the fisher or finder was contacted to provide additional data on specimens, such as size and condition of the animals, precise location, fishing method if applicable, and supporting photographic documentation. In addition, we performed a database search of two citizen science applications for reporting of wildlife sightings: the *eTurtle*, application developed specifically for reporting sea turtle findings (Euroturtles, 2022a), and the *GBIF*, the largest global biodiversity data set with open-access (Global Biodiversity Information Facility, 2022). We used "green sea turtle", "green turtle" or "*Chelonia mydas*" as a search term and narrowed the search to the Adriatic Sea. Only those reports supported by photographic material allowing reliable identification of the species are presented (Fig. 1).

We have also conducted a review of published data from literature through Google Scholar (2022), Web of Science (2022) and Marine Turtle Newsletter (2022) using combination of keywords ("*Chelonia mydas*", "green turtle", "green sea turtle" and "Adriatic Sea"), with latest search during manuscript submission process in August 2022. The resulting publications were screened and only those with reliable records of green turtles were included in further analysis. We cross checked data from different literature sources to avoid duplication of records. Unconfirmed records not supported by evidence were excluded from the study.

We analyzed the number of green turtle records in Adriatic Sea for three time periods: historic (before year 1980), past (between 1980 and 1999), and recent (2000 and later) when the green turtle population in the Mediterranean experienced an increase in the number of nests (Casale *et al*., 2018). Due to low number of historic records and possible cases of misidentification of green and loggerhead turtles (Lazar *et al*., 2004), size distribution, using curved carapace length (CCL) and temporal distribution analyses were performed only for findings from 1980 onwards when these data were available.

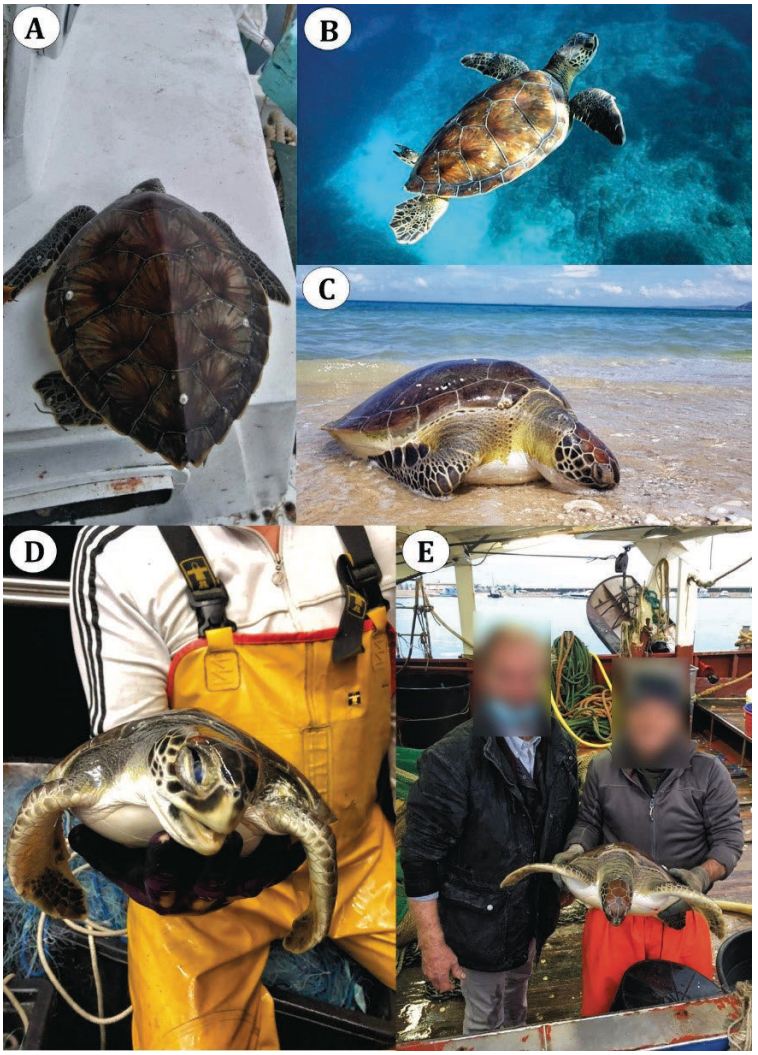

Fig. 1. Example of new observations of green sea turtles in the Adriatic Sea. *A)* Tab. 1, Record number 68 (Photo: M. Ossich). *B)* Record N. 72 (Photo: A. Žuljević). *C)* Record N. 73 (Photo: M. Schoonderwoerd). *D)* Record N. 74 (Photo: D. Jugovac). *E)* Record N. 69 (Photo: P. Salvemini).

RESULTS AND DISCUSSION

We conservatively present findings of 75 green turtles in the Adriatic Sea (Tab. 1 and references therein), including eight unpublished records obtained between 2015 and 2020 (Tab. 1, Record numbers 60, 65 – 66, 68, 72 – 75; Fig. 1). All new records were juvenile animals with curved carapace length (CCL) < 50 cm, originating from southern Adriatic (Italy and Albania; N = 5) and Croatian part of north-eastern Adriatic (N = 3). Five out of eight new records resulted from fishery bycatch (Fig. 1A, D, E) and two individuals were found stranded (Fig. 1C). One green turtle was observed and reported alive in Karin Bay, Croatia (Fig. 1B), flipper tagged (HR1751 and HR1752) and released.

Apart from three historical records, all other Adriatic green turtle findings (96%) occurred since the year 1980. The number of recent, post-2000 records (N = 66) is more than ten-fold higher compared to the previous 20-year period (N = 6, Tab. 1, Fig. 2). The size of animals ranged between 22.5 and 79.5 cm CCL (mean ± SD: 38.4 ± 14.4 cm, N = 60), with most turtles (78.3%) being small juveniles of 25 – 40 cm CCL (Fig. 3). The most records came from the warm period of year, between May and October (84.8%, N = 66; Fig. 4), and from the southern Adriatic (86.1%, N = 72; Fig. 2). No information on the method of observations exist for historical records, whilst in other cases most of turtles were bycaught in fisheries (73.6%), followed by strandings (16.7%) and observation of animals at sea (4.2%). Data on method on observation were unavailable for four individuals.

When compared with the loggerhead turtle, for which bycatch in Adriatic fisheries has been estimated at several thousand catches per year (Casale, 2011; Baldi *et al*., 2022), the number of green turtle records in the Adriatic Sea is low. This is not comple-

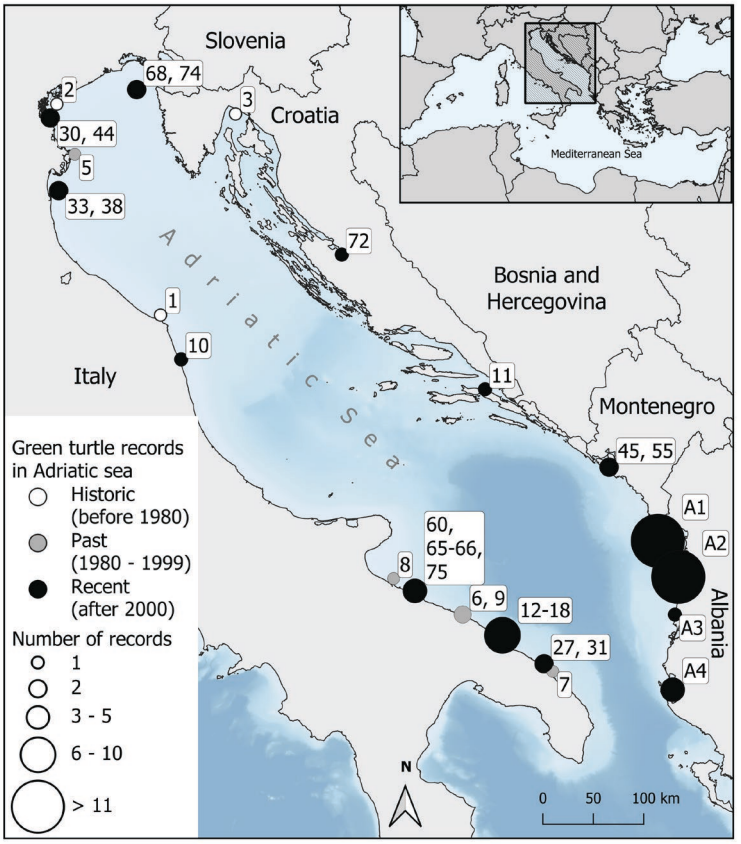

Fig. 2. Historic, past and recent records of green sea turtle in Adriatic Sea. Locations are slightly adapted to avoid over-plotting. Numbers in frames correspond to Record Numbers values in Tab. 1, apart from: A1 (Record numbers 19-26, 28-29, 32, 35-37), A2 (39, 41-43, 46-50, 53-54, 56-59, 61-64, 69-71), A3 (40) and A4 (34, 51-52, 67, 73). Record with unknown location (Tab 1., Record number 4) was omitted from the map. Records from Storelli *et al.* (2008) are displayed as a group at southern Adriatic Italian coast, as the exact locations were undisclosed (Tab. 1, Record numbers 12-18).

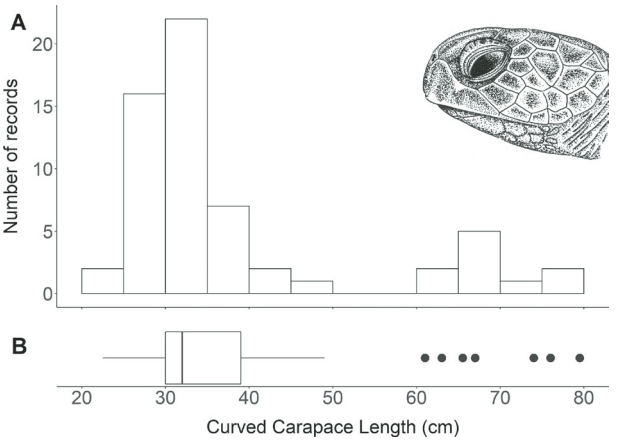

Fig. 3. Size distribution of green sea turtles in Adriatic Sea (N = 62). A) Frequency histogram with 5 cm length classes. B) Boxplot with the box representing values between 25th and 75th percentile and whiskers extending to a maximum of 1.5 times inter-quantile range. Inset green sea turtle artwork by Manja Tišler.

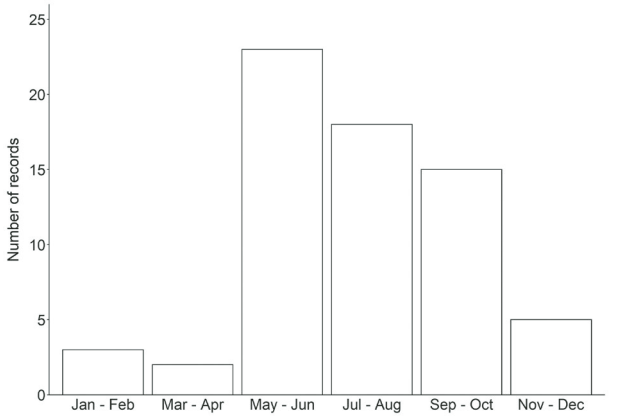

Fig. 4. Bimonthly temporal distribution of green sea turtle records in the Adriatic Sea (N = 66).

tely unexpected, as Mediterranean green turtle population is much smaller, estimated at around 3,400 adults compared to almost 16,000 adult loggerheads (Casale & Heppell, 2016). Also, the green turtle is a thermophilic species, primarily inhabiting warmer waters of the eastern Mediterranean, with oceanic habitats in the Levantine basin and neritic foraging grounds along the coast of Turkey and northern African shelf (Stokes *et al.*, 2015; Casale *et al.*, 2018). Despite the expectedly low overall number of Adriatic findings, the over ten-fold increase since 2000 is intriguing.

There are several plausible explanations for this. First, the increase in the number of primarily small-sized juveniles in Adriatic during the recent period may be a direct result of increasing Mediterranean green turtle populations (Casale *et al.*, 2018). For example, at thirteen nesting beaches with a regular monitoring of nesting activity for at least 10 years the increase was estimated at 270% since the late 1980s/early 1990s

Tab. 1: Records of green sea turtles in Adriatic Sea. CL – carapace length, CCL - curved carapace length.

Record Number	Date	Country	Location	Size / Weight	Remarks	Source
Historic (before 1980)						
1	1830	Italy	Ancona	"Length": 45.7 cm		1, 2
2	1864 Jul	Italy	Malamocco, Venice	CL: 28 cm		1, 2
3	1885 Sep 9	Croatia	Rijeka (Fiume) Bay	Weight: 18 kg		3
Past (1980 – 1999)						
4	1980 - 89	Italy	Unknown	CL: 28 - 31 cm		4
5	1985 Aug	Italy	Po River Delta	CL: 30 cm	Incidental capture	5
6	1986 Jul	Italy	Bari	CL: 28 - 31 cm	Incidental capture	6
7	1991 Feb 1	Italy	Lido S. Anna, Brindisi	CL: 31,5 cm		4
8	1996 Jul	Italy	Margherita di Savoia	Weight: 4 kg	Incidental capture	5
9	1998 Apr 3	Italy	Torre a Mare, Bari	CL: 31 cm	Stranded, cold stunned	4,7
Recent (after 2000)						
10	2000 Aug 25	Italy	Porto S. Elpidio, Ascoli Piceno	CCL: 35 cm	Dead	8
11	2001 Dec 14	Croatia	Trpanj, Pelješac Peninsula	CCL: 40 cm	Incidental capture (gillnet), dead	5
12 - 18	2001 - 2004	Italy	South Adriatic	CL: 30.5 ± 6.1 cm	Stranded, 7 animals, dead or died after stranding	9
19	2003 May	Albania	Drini bay	CCL: 27 cm	Incidental capture, stavnik, alive	10, 11, 12
20	2003 Aug	Albania	Drini bay	CCL: 29 cm	Incidental capture, stavnik, alive	10, 11, 12
21	2003 Sept	Albania	Drini bay	CCL: 67 cm	Incidental capture, stavnik, alive	10, 11, 12
22	2004 May 5	Albania	Drini bay	CCL: 33 cm	Incidental capture, stavnik, alive	10, 11, 12
23	2004 Jul 2	Albania	Drini bay	CCL: 33 cm	Incidental capture, stavnik, alive	10, 11, 12
24	2004 Aug 17	Albania	Drini bay	CCL: 39 cm	Incidental capture, stavnik, alive	10, 11, 12
25	2005 May 25	Albania	Drini bay	CCL: 39 cm	Incidental capture, stavnik, alive	10, 12
26	2005 Jun 6	Albania	Drini bay	CCL: 38 cm	Incidental capture, stavnik, alive	10, 12
27	2006 Feb 8	Italy	Brindisi	CCL 40 cm	Dead	8
28	2006 May 9	Albania	Drini bay	CCL: 32 cm	Incidental capture, stavnik, alive	10
29	2006 May 29	Albania	Drini bay	CCL: 30 cm	Incidental capture, stavnik, alive	10
30	2006 Jun 8	Italy	Venice Lagoon	CCL:74 cm	Dead, floating	13

Tab. 1: Continued

Record Number	Date	Country	Location	Size / Weight	Remarks	Source
31	2008 Feb 21	Italy	Punta Penne, Brindisi	CCL: 35.2 cm	Stranded, cold stunned	8
32	2008 Jun 4	Albania	Drini bay	CCL: 39 cm	Incidental capture, stavnik, alive	10, 14
33	2009 Sep 22	Italy	Ferarra, Lido di Nazioni	CCL: 29.5	Stranded alive, died due to injuries	15
34	2009 Oct 6	Albania	Vlora bay	CCL: 30 cm	Incidental capture	10, 14
35	2010 Jun 23	Albania	Drini bay	CCL: 33 cm	Incidental capture, stavnik, alive	10, 14
36	2010 Jun 23	Albania	Drini bay	CCL: 67 cm	Incidental capture, stavnik, alive	10, 14
37	2010 Jul 21	Albania	Drini bay	CCL: 65.5 cm	Incidental capture, stavnik, alive	10, 14
38	2010 Oct 12	Italy	Porto Garibaldi	CCL: 38.5	Incidental capture, trawl	15
39	2011 Jul 20	Albania	Drini bay	CCL: 28 cm	Incidental capture, stavnik, alive	10
40	2011 Jul 25	Albania	Spille	CCL: 30 cm	Incidental capture, setnets, dead	10
41	2012 May 29	Albania	Drini bay	CCL: 33.5 cm	Incidental capture, stavnik, alive	10
42	2012 Aug 3	Albania	Drini bay	CCL: 32 cm	Incidental capture, stavnik, alive	10
43	2012 Aug 24	Albania	Drini bay	CCL: 34 cm	Incidental capture, stavnik, alive	10
44	2012 Sep 9	Italy	Venice Lagoon	CCL: 30 cm	Dead, floating	13
45	2013 May 10	Montenegro	Kotor Bay, Bigova	Not available	Incidental capture, gillnet, alive	16
46	2013 May 23	Albania	Drini bay	CCL: 29 cm	Incidental capture, stavnik, alive	10
47	2013 May 23	Albania	Drini bay	CCL: 32 cm	Incidental capture, setnets, alive	10
48	2013 Jun 17	Albania	Drini bay	CCL: 67 cm	Incidental capture, stavnik, alive	10
49	2013 Aug 26	Albania	Drini bay	CCL: 79.5 cm	Incidental capture, stavnik, alive	10
50	2013 Oct 30	Albania	Drini bay	CCL: 65.5 cm	Incidental capture, stavnik, alive	10
51	2013 Dec 5	Albania	Vlora bay	CCL: 31 cm	Incidental capture, trawl, alive	10
52	2014 Apr 14	Albania	Vlora bay	CCL: 32 cm	Incidental capture, trawl, alive	10
53	2014 Jul 18	Albania	Drini bay	CCL: 30 cm	Incidental capture, stavnik, alive	10
54	2014 Aug 11	Albania	Drini bay	CCL: 31 cm	Incidental capture, stavnik, alive	10
55	2014 Sep 6	Montenegro	Kotor bay, Orahovac	"Juvenile"	Incidental capture (gillnet), alive	16
56	2014 Sept 20	Albania	Drini bay	CCL: 63 cm	Incidental capture, stavnik, alive	10
57	2014 Sept 20	Albania	Drini bay	CCL: 31 cm	Incidental capture, stavnik, alive	10

Tab. 1: Continued

Record Number	Date	Country	Location	Size / Weight	Remarks	Source
58	2014 Sept 20	Albania	Drini bay	CCL: 30 cm	Incidental capture, stavnik, alive	10
59	2014 Oct 2	Albania	Drini bay	CCL: 76 cm	Incidental capture, stavnik, alive	10
60	2015 Jun 2	Italy	Margherita di Savoia	CCL: 31 cm	Stranded, dead	17
61	2015 Jun 22	Albania	Drini bay	CCL: 29 cm	Incidental capture, stavnik, alive	10
62	2015 Jul 10	Albania	Drini bay	CCL: 24.5 cm	Incidental capture, stavnik, alive	10
63	2016 May 2	Albania	Drini bay	CCL: 22.5 cm	Incidental capture, stavnik, alive	10
64	2016 May 20	Albania	Drini bay	CCL: 27 cm	Incidental capture, stavnik, alive	10
65	2016 Oct 26	Italy	Trani	CCL: 32 cm	Incidental capture, trawl, alive	17
66	2016 Nov 24	Italy	Molfetta, Giovinazzo	CCL: 30 cm	Incidental capture, trawl, alive	17
67	2017 Jun 21	Albania	Vlora bay	CCL: 35 cm	Incidental capture, setnets, alive	10
68	2017 Oct 17	Croatia	Savudrija	CCL: ≅	Incidental capture, gillnet, dead	17
69	2017 Nov 5	Albania	Drini bay	CCL: 29.5 cm	Incidental capture, stavnik, alive	10
70	2018 May 11	Albania	Drini bay	CCL: 33 cm	Incidental capture, stavnik, alive	10
71	2018 May 31	Albania	Drini bay	CCL: 61 cm	Incidental capture, stavnik, alive	10
72	2018 Aug 12	Croatia	Gornji Karin	30 - 50 cm	Observation, alive	17
73	2019 May 15	Albania	Vlora Bay	Not available	Stranded	17*
74	2019 Oct 28	Croatia	Savudrija	CCL: ≅	Incidental capture, gillnet, dead	17
75	2020 Dec 3	Italy	Bisceglie	CCL: 49 cm	Incidental capture, trawl, alive	17

Sources: 1 – Nardo, 1864 in Lazar *et al.*, 2004; **2** – De Betta, 1970 in Lazar *et al.*, 2004; **3** – Depolli, 1898 in Lazar *et al.*, 2004; **4** – Pastorelli, 1999 in Lazar *et al.* 2004; **5** – Lazar *et al.*, 2004; **6** – Basso, 1992 in Lazar *et al.*, 2004; **7** – Centro Studi Cetacei, 2000 in Lazar *et al.*, 2004; **8** – Bentivegna *et al.*, 2011; **9** – Storelli *et al.*, 2008; **10** – Piroli & Haxhiu, 2020b; **11** – Haxhiu & Rumano, 2005; **12** – Haxhiu & Rumano, 2006; **13** – Garofalo *et al.*, 2014; **14** – White *et al.*, 2011b; **15** – Vallini *et al.*, 2014; **16** – Gvozdenović *et al.*, 2016; **17** – This study; *de Vries & Lemmens, 2020 (Recommended citation of the GBIF database record).

(Broderick *et al*., in review). Secondly, institutional capacity for research and monitoring of sea turtles in Mediterranean significantly improved in the recent years (Casale *et al*., 2018), with conservation focus shifting from exclusively nesting sites in 1980s and 1990s to developmental and foraging marine habitats, including the Adriatic Sea. The Adriatic Sea is shared by six countries, three of which are member states of the European Union (EU), legally bound to protect sea turtles as priority species under the Habitats directive (Directive 92/43/EEC). Both loggerheads and green turtles are listed as indicators of good environmental status under Marine Strategy Framework Directive (Directive 2008/56/EC). Stemming from this legislative framework of the EU, several regional projects, co-funded by the EU, aimed at sea turtle conservation were implemented in the Adriatic region, such as NETCET IPA (https://www.blue-world.org/what-we-do/our-projects/netcet/), TARTALIFE (tartalife.eu), LIFE EUROTURTLES (euroturtles.eu/) and LIFE MEDTURTLES (medturtles.eu). These projects included awareness raising campaigns specifically targeting fishers to recover and report sea turtle findings. Over the last decade more than 1000 fishers have been approached and trained in techniques for recovering comatose sea turtles (e.g., Netcet, 2015; Euroturtles, 2022b). These large-scale sensitization actions in all Adriatic countries certainly contributed to increased numbers of opportunistic green turtle reports by fishers and stranding networks in the region (30.6%; N = 23). Although these findings are a result of increased awareness, we argue that this is not the only contributor to such high increase in the number of Adriatic records in the recent period. Namely, records from Albania, which represent over half (62.1%) of recent green turtle records in Adriatic, came from a long-term monitoring program implemented since 2002 (Haxhiu & Rumano, 2005; White *et al*., 2011a; White *et al*., 2011b; Haxhiu & Piroli, 2013; Saçdanaku & Haxhiu, 2015; Piroli & Haxhiu, 2020b). The number of green turtle records in Albania increased by 73.3% since 2011, although regular monitoring expansion and awareness campaigns could have been a contributing factor (Piroli, 2021). Our results hence suggest that the recent increase in the number of green turtle records is also due to the increasing number of predominantly small juveniles frequenting Adriatic Sea.

The post-hatchling and juvenile life-history of Mediterranean green turtle is poorly known (Casale *et al*., 2018) with sea currents playing a crucial role in dispersal to and within oceanic habitats. Present knowledge on dispersal routes and high-density areas for early oceanic juveniles is based upon numerical simulations of particle distribution (Putman & Naro-Maciel, 2013; Casale & Mariani, 2014), and has suggested that the Levantine Basin is the main pelagic habitat for this species. Prevailing surface circulation system in the eastern Mediterranean (Menna & Poulain, 2010) facilitates further dispersal of oceanic juveniles to Ionian Sea and southern Adriatic, particularly for green turtles from nesting sites in Turkey (Casale & Mariani, 2014). The presence of animals with CCL ≤40 cm in Lakonikos Bay, Greece (Margaritoulis & Panagopoulou, 2010) and majority of Adriatic records belonging to small-sized individuals (Tab. 1; Fig. 3) further corroborate existence of the Ionian-Adriatic developmental pathway of green turtle in Mediterranean (Lazar *et al*., 2004, 2010).

Another factor that has likely contributed to increased number of green turtles frequenting Adriatic Sea is raising sea temperatures. The Adriatic Sea is a temperate sea characterized by seasonal and latitudinal temperature variability, with average summer sea surface temperatures (SST) ranging between 23 and 25 °C (Lipizer *et al*., 2014; Grilli *et al*., 2020). A warming trend has been observed since 1970s (Grilli *et al*., 2020), with prominent northward shifts of isotherms since 1993 (Pisano *et al*., 2020),

and yearly SST increase of 0.07 °C since 2003 (García-Monteiro *et al*., 2022). The warming trend is more pronounced during spring and summer with several extremely warm years due to heatwaves (Pisano *et al*., 2020). Ocean warming may establish dynamic and recurring thermal corridors leading to shifts in the distribution and migratory pathways of highly vagile marine megafauna, as documented for loggerhead turtles in North Pacific (Briscoe *et al*., 2021). Rising SST and temperature anomalies in the past two decades already resulted in dozens of northward range extensions and biological invasions of thermophilic species in the Adriatic Sea (Lipej *et al*., 2022; Azzurro *et al*., 2019), and may have facilitated the immigrations of juvenile green turtles too. As small juveniles are able to intentionally deviate from prevailing currents to pelagic nursery or foraging areas (Putman & Mansfield, 2015; Mansfield *et al*., 2021), these thermal anomalies might have been a crucial environmental cue for entering the Adriatic Sea. In case of the loggerhead turtle, migratory corridors of adult individuals from eastern Mediterranean rookeries towards Adriatic are predicted to warm continuously for 0.24 °C per decade (Almpanidou *et al*., 2019) with future SST increases due to climate change (Intergovernmental Panel's on Climate Change, 2019). These migratory corridors overlap with the Ionian-Adriatic developmental pathway of green turtles, suggesting that suitable thermal corridors towards Adriatic might occur more frequently or even become permanent.

The green turtle exhibits high regionally specific dietary plasticity characterized by a trade-off between local availability of prey items and its nutritional value (Campos & Cardona, 2020). Moreover, the species dietary preferences seem to be linked to SST, with higher levels of herbivory observed at higher SST (>25°C; Esteban *et al*., 2020). When compared with the green turtle diet composition in Mediterranean (Cardona *et al*., 2010; Palmer *et al*., 2021), the Adriatic Sea provides multiple food sources in both pelagic and neritic areas. A diverse gelatinous zooplankton communities are typical for pelagic habitats of the southern Adriatic (Batistić *et al*., 2004) while neritic areas of the Adriatic host abundant benthic invertebrate communities (Cantone, 2003; Bakran-Petricioli *et al*., 2006; Frontalini *et al*., 2011; Prampolini *et al*., 2021), algal assemblages (Falace *et al*., 2010), and *Posidonia oceanica* (Telesca *et al*., 2015) and *Cymodocea nodosa* sea grass meadows (Chefaoui *et al*., 2016), thus defining the Adriatic as a potentially suitable foraging area for the species. The Adriatic foodscape, however, might drastically change in the future, with projected reduction of *C. nodosa* habitats by 46% and disappearance of *P. oceanica* meadows by the end of this century due to climate change (Chefaoui *et al*., 2018). Declines of native species is expected to propel the spread of invasive seagrass *Halophila stipulacea* (Wesselman *et al*., 2021) that is present in Vlora Bay in Albania since 1990s (Kashta, 1992), and which constitutes the most important part of green turtle diet in Cyprus (Palmer *et al*., 2021). Although such predictions include some degree of uncertainty, with expected changes in SST and food availability, the Adriatic Sea is likely to play increasingly more important role for recovering Mediterranean green turtle populations in the future.

With the fishing fleet of more than 10,000 active vessels, the Adriatic Sea is one of the heaviest fished regions of the Mediterranean (FAO, 2020) and a hotspot of sea turtle bycatch (Casale, 2011). About 74% of Adriatic green turtle records resulted from fisheries interactions. In Albania, bycatch occurred mostly in "*stavnik"* nets (80.7%), an artisanal passive fishing gear that has resulted in no mortality since the start of the monitoring program. So far, no deaths have been recorded in bottom trawls too, but 4 out of 6 individuals bycaught in small-scale set net fishery have been found dead. With

increase in green turtle hatchling production on Mediterranean beaches and future sea warming it is reasonable to expect that the presence of this species in Adriatic will continue to increase. Consequently, the number of incidental catches and deaths will likely increase as well. As the survival of immature turtles is one of the key population abundance drivers in Mediterranean (Omeyer *et al.*, 2021), understanding their at-sea distribution, habitat use and interactions with fisheries will be crucial information useful to inform conservation measures and avoid the Adriatic Sea becoming a sink habitat for Mediterranean green turtle population.

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