



# Epidemiology of *Sulcascaris sulcata* (Nematoda: Anisakidae) ulcerous gastritis in the Mediterranean loggerhead sea turtle (*Caretta caretta*)

Mario Santoro<sup>1</sup> · Erica Marchiori<sup>2</sup> · Doriana Iaccarino<sup>1</sup> · Barbara degli Uberti<sup>1</sup> · Rudi Cassini<sup>2</sup> · Fabio Di Nocera<sup>1</sup> · Anna Cerrone<sup>1</sup> · Giorgio Galiero<sup>1</sup> · Federica Marcer<sup>2</sup>

Received: 21 December 2018 / Accepted: 1 March 2019 / Published online: 11 March 2019  
© Springer-Verlag GmbH Germany, part of Springer Nature 2019

## Abstract

*Sulcascaris sulcata* Rudolphi 1819 is a gastric nematode parasite of sea turtles. Here, we report the occurrence and describe for the first time the pathological changes caused by *S. sulcata* in the Mediterranean loggerhead sea turtle (*Caretta caretta*) stranded along the Tyrrhenian coast and northern Adriatic coast of Italy. Prevalence of infection was significantly higher in loggerhead sea turtles from the Adriatic Sea. Both prevalence and abundance of infection showed an increasing trend along with host age classes from both geographical localities. Nevertheless, while many small loggerhead sea turtles were found infected from the Adriatic Sea, only bigger individuals were infected from the Tyrrhenian Sea. The most common gross pathological change was a mucous gastritis with focal to multifocal raised ulcerous lesions roundish to irregular in shape ranging from 1 to over 20 cm in length, and cream-yellowish to greenish in color. The severity grade of gastritis increased with higher number of *S. sulcata* individuals. Microscopic pathological changes ranged from atrophic gastritis with heterophilic infiltration in the lamina propria to the destruction of the mucosal and sub-mucosal surfaces and necrosis. Results here obtained demonstrate that *S. sulcata* may cause ulcerous gastritis in both samples of loggerhead sea turtles studied from the Mediterranean Sea. Observed differences in *S. sulcata* infection among the different host age classes and between the two studied basins are likely linked to the differences of regional habitat and intermediate prey host availability.

**Keywords** Ascaridoidea · Nematode parasite · Pathological changes · Parasitic gastritis · Sea turtle · Mediterranean Sea

## Introduction

The parasitic nematode genus *Sulcascaris* Hartwich, 1957 belongs to the superfamily Ascaridoidea and tribe Anisakinae which include also *Anisakis* Dujardin 1845, *Phocanema* Myers 1959, and *Terranova* Leiper and Atkinson 1914 (see Hartwich 2009). At present, *Sulcascaris sulcata* Rudolphi, 1819 is the only species in the genus. It shows a wide distri-

bution in warm marine waters including Mediterranean and Caribbean Seas, and the South Atlantic, Western Atlantic, and Western Pacific Oceans where it naturally matures in the loggerhead sea turtle (*Caretta caretta*), green sea turtle (*Chelonia mydas*), and Kemp's ridley sea turtle (*Lepidochelys kempii*) (Sey 1977; Lichtenfels et al. 1978; Berry and Cannon 1981; Vicente et al. 1993; Wernick et al. 2008; Santoro et al. 2010a; Greiner 2013).

The life history of *S. sulcata* was elucidated experimentally. It has been demonstrated that hatchling loggerhead sea turtles become infected by ingesting scallops infected with fourth-stage larvae *S. sulcata* (Berry and Cannon 1981). Larvae attach at the base of the esophagus where four molts occur about 3 weeks after infection and mature to adults in at least 5 months. Adult parasites living in the stomach of the host and eggs are shed in the marine environment with feces. Two molts occur in the egg to the third-stage larva which spontaneously hatches and develops in bivalve mollusks and

Section Editor: Guillermo Salgado-Maldonado

✉ Mario Santoro  
mario.santoro@izsmportici.it

<sup>1</sup> Istituto Zooprofilattico Sperimentale del Mezzogiorno, 80055 Portici, Italy

<sup>2</sup> Department of Animal Medicine, Production and Health, University of Padova, 35020 Legnaro, Italy

gastropods to fourth-stage larva after 3–4 months. It was hypothesized that the duration of the natural cycle could be of 2 years (Berry and Cannon 1981).

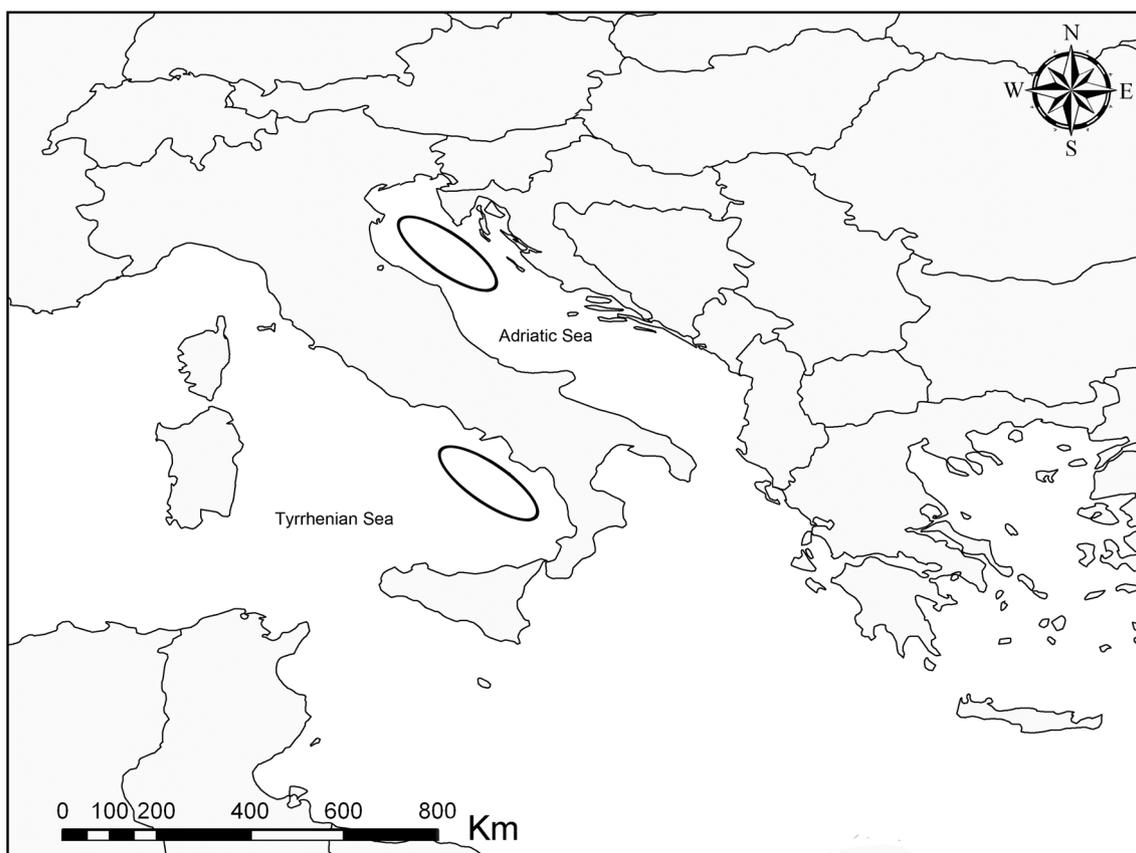
In the Mediterranean loggerhead sea turtle, the prevalence of infection by *S. sulcata* ranges from 20 to 25% (Sey 1977; Santoro et al. 2010a; Gračan et al. 2012). Despite this, no report focused on the pathological changes that this nematode may inflict to its definitive host. Here, we report on the occurrence and describe for the first time the pathological changes caused by *S. sulcata* in the Mediterranean loggerhead sea turtles stranded along the Tyrrhenian and the northern Adriatic coasts of Italy.

## Materials and methods

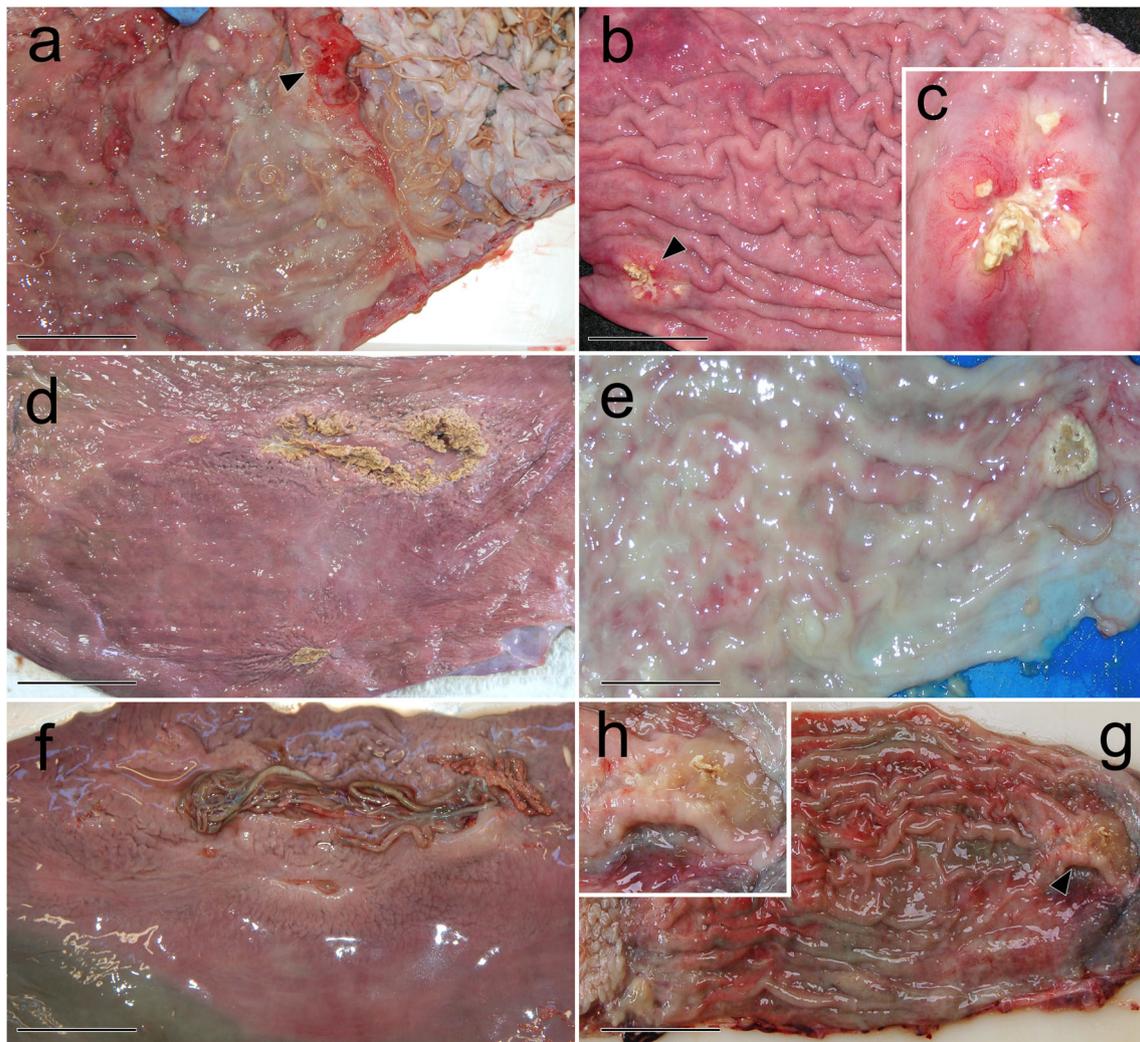
A total of 218 loggerhead sea turtles stranded from January 2013 to October 2018 along the Tyrrhenian coast ( $n = 85$ ) of Campania region and northern Adriatic coast ( $n = 133$ ) of Veneto region in Italy (Fig. 1) were studied for *S. sulcata* occurrence and associated pathologies. For each turtle, the curved carapace length (CCL) was measured to the nearest centimeter. Turtles were categorized into the following age classes (Bolten 1999): early juveniles (CCL  $\leq 40$  cm), large juveniles (CCL between 41 and 69 cm), and adults (CCL  $\geq 70$  cm).

During postmortem examination, the whole digestive tract including the esophagus, stomach, and intestine of each turtle was examined separately for *S. sulcata* specimens and associated lesions. Sections of the digestive tract were opened and surfaces were examined visually, then washed through a 100- $\mu\text{m}$  mesh screen. The remaining washed material from each tract was examined carefully under a dissecting microscope, and any nematodes were collected, counted, and rinsed in saline solution and preserved in ethanol 70% (Santoro et al. 2018). Nematodes were cleared in lactophenol and were classified following the identification key proposed by Sprent (1977).

In loggerhead sea turtles with the presence of *S. sulcata* specimens, a digital photography of gastrointestinal tract was taken at each postmortem examination, for tissue injuries related to this nematode. A gross subjective severity scoring system was established in which a stomach completely free of visible lesions was scored as 0; a stomach with hyperemia and few sub-mucosal petechia with no other visible lesions in the mucosa was scored as 1; a stomach with extensive areas of erosions or a single raised ulcer was scored as 2; and a stomach with multiple ulcers was scored as 3 (Fig. 2). Selected samples for histological examination of the esophagus, stomach, and intestine were fixed in 10% neutral phosphate-buffered formalin and processed by routine methods into



**Fig. 1** Stranding areas of loggerhead sea turtles studied for *Sulcascaaris sulcata* infection in the Adriatic and Tyrrhenian Seas



**Fig. 2** Gross pathological changes by *Sulcascaris sulcata* in the stomach of loggerhead sea turtles. Stomach with hyperemia and few sub-mucosal petechia (arrowhead) is scored as 1 (**a**); stomach with extensive areas of erosions or a single raised ulcer (arrowhead) is scored as 2 (**b**, **c**); and a

stomach with multiple ulcers is scored as 3 (**d**, **e**, **f**, **g**, **h**). Arrowheads in **b** and **g** indicate the lesions showed enlarged in **c** and **h**, respectively. Bar = 5 cm

paraffin blocks which were cut into 3  $\mu\text{m}$  thick sections and stained with hematoxylin and eosin.

Prevalence of infection and abundance (mean number of *S. sulcata* individuals among studied loggerhead sea turtles) were displayed using a simple descriptive statistics. Differences in prevalence values among sampling areas (Tyrrhenian vs. Adriatic) and host age classes were investigated by means of Pearson's chi-squared test. Differences in abundance values among geographical sites and host age classes were assessed through a nonparametric approach, using the Mann–Whitney *U* test or the Kruskal–Wallis test. Similarly, loggerhead sea turtles with different gross severity scores (0–3) were assessed to unveil differences in number of harbored *S. sulcata* individuals. The overall level of statistical significance was set to  $p < 0.05$ . Statistical analyses were performed using the software IBM SPSS Statistics 25.

## Results

In general, the digestive tracts from a total of 218 loggerhead sea turtles were examined, and 54 (24.8%) of those were positive for individuals of *S. sulcata*, with an abundance of 7.1 specimens (range, 0–287).

Out of a total of 85 carcasses of loggerhead sea turtles from the Tyrrhenian Sea (CCL mean,  $63 \pm 12.7$  SD (standard deviation); ranging from 11.7 to 90.8 cm), 14 (16.5%) were infected by *S. sulcata* individuals. Infected individuals from the Tyrrhenian Sea had a CCL ranging from 57 to 81.8 (mean,  $64.4 \pm 4.6$  SD) cm. Of the 14 loggerhead sea turtles with *S. sulcata* infection, we found gross pathological change in 10 (71.4%) of those.

Out of a total of 133 carcasses of loggerhead sea turtles (CCL mean,  $52.6 \pm 14.9$  SD; ranging from 20 to 87 cm) from

the Adriatic Sea, 40 (30.1%) were infected by *S. sulcata*. Infected individuals from the Adriatic Sea had a CCL ranging from 33 to 85 (mean,  $59.4 \pm 14.3$  SD) cm. Of the 40 loggerhead sea turtles with individuals of *S. sulcata* from the stomach, 10 were too badly preserved for the evaluation of the severity grade of gastritis, while we found gross pathological changes in 29 out of the remnant 30 loggerhead sea turtles (96.7%).

Prevalence of infection for *S. sulcata* and abundance values from the Tyrrhenian and Adriatic Seas according to the host age classes are shown in Table 1, with associated significant differences. Prevalence of infection was significantly higher in loggerhead sea turtles from the Adriatic Sea ( $p < 0.05$ ), whereas abundance was similar between the two areas. Both prevalence and abundance showed an increasing trend along with host age classes ( $p < 0.01$  and  $p < 0.05$ , respectively). Abundance according to the assigned gross severity score is displayed in Table 2. Only animals assigned with grade 3 showed higher abundance ( $p < 0.05$ ), compared with other groups.

The most common gross pathological change was a mucous gastritis with sharply demarcated focal to multifocal raised ulcerous lesions (Fig. 2). Intralesional *S. sulcata* specimens were common (Fig. 2f). Ulcerous lesions were roundish to irregular in shape ranging from 1 to over 20 cm in length, and cream-yellowish (in recent infection) (Fig. 2b, c, and e) to greenish in color (in older infection) (Fig. 2d, f, g, and h). In most cases, *S. sulcata* specimens were strongly attached by the buccal capsule to the gastric surface penetrating the mucosa and the sub-mucosa, and causing hyperemia, multifocal hyperplastic reactive inflammation, thickening, and petechial hemorrhages. Most of *S. sulcata* individuals were aggregated around and inside the ulcerated and eroded areas. Microscopic pathological changes ranged from the presence of heterophilic inflammatory infiltrates in the lamina propria to atrophic gastritis with destruction of the mucosal and sub-mucosal surfaces and necrosis (Fig. 3b, c). Cross sections of adult specimens of *S. sulcata* and their eggs were common findings

**Table 2** General data of grades of gross severity score of gastritis by *Sulcascares sulcata* and their abundance (mean) in loggerhead sea turtles from the Adriatic and Tyrrhenian Seas. Out of a total of 54 loggerhead sea turtles with *S. sulcata* individuals, only 44 were evaluated for gross severity score

		Postmortem			
		Examined	Abundance*	SD	Range
Grade	0	5	2.0 <sup>a</sup>	2.2	1–6
	1	8	12.1 <sup>ab</sup>	14.0	1–43
	2	20	9.5 <sup>a</sup>	12.6	1–54
	3	11	104.6 <sup>b</sup>	124.2	6–287

\*Different letters refer to values with significant differences ( $p < 0.05$ ) at the Kruskal–Wallis test; SD, standard deviation

inside the lesions (Fig. 3b, c). Eggs of *S. sulcata* were also observed histologically from the surface of esophageal papillae with no associated pathological changes (Fig. 3a).

## Discussion

Results here obtained demonstrate that *S. sulcata* may cause ulcerous gastritis in loggerhead sea turtles from the Tyrrhenian and Adriatic Seas. There are no previous published reports of *S. sulcata* causing pathological changes in the Mediterranean basin. We were able to find in published literature just two records both from Australian loggerhead sea turtles. Lester et al. (1980) described the lesions by *S. sulcata* in five loggerhead sea turtles as ulcers penetrating into the sub-mucosa of the stomach wall. Berry and Cannon (1981) described the life cycle of *S. sulcata* experimentally and included a microscopic figure (in their Fig. 15) of a stomach of a free-ranging loggerhead sea turtle from the Western Australia showing the complete destruction of its upper mucosa.

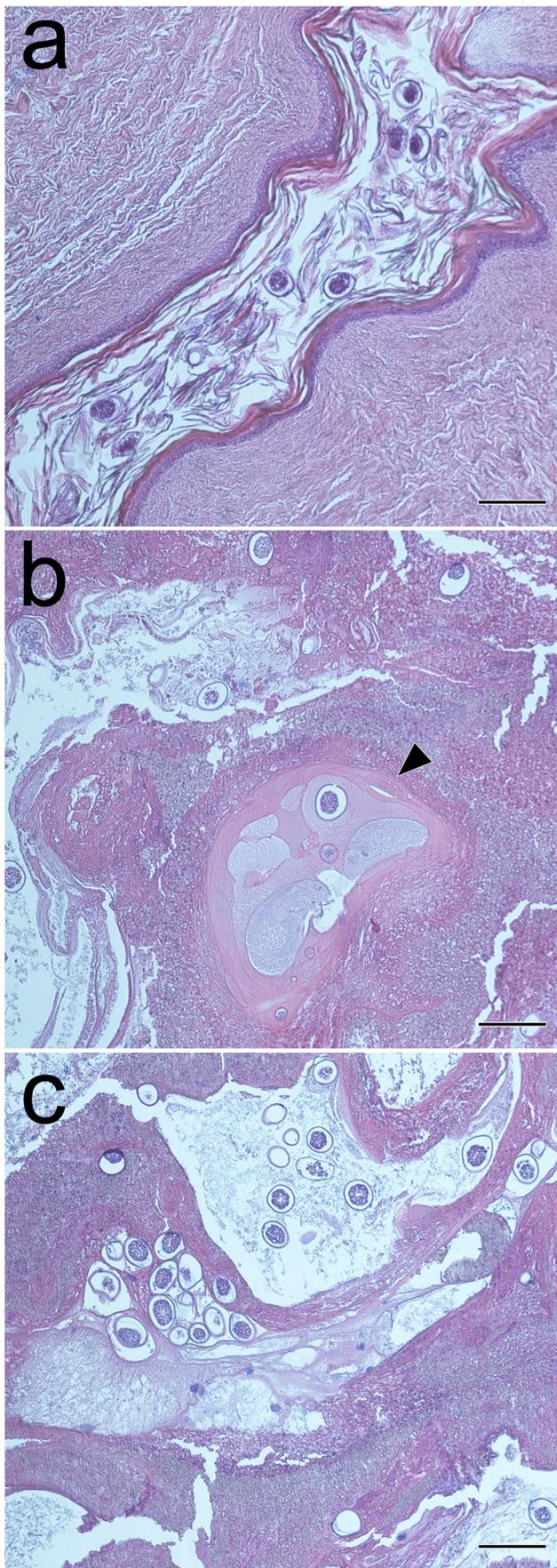
Pathological changes of the digestive tract associated with helminth parasites are uncommon in loggerhead sea turtles

**Table 1** Prevalence (%) and abundance values (mean) of *Sulcascares sulcata* infection in loggerhead sea turtles from the Adriatic and Tyrrhenian Seas, according to the different host age class. EJ, early juveniles; LJ, large juveniles; A, adults; SD, standard deviation

		Gut examination						
		Examined	Positive (individuals)	Prevalence	<i>p</i> value*	Abundance**	SD	Range
Geographical site	Tyrrhenian	85	14	16.5	0.02	10.4	49.5	0–287
	Adriatic	133	40	30.1		4.9	23.0	0–244
Age class	EJ	34	5	14.7	< 0.01	0.4 <sup>a</sup>	1.2	0–6
	LJ	146	32	21.9		5.2 <sup>a</sup>	30.5	0–282
	A	38	17	44.7		21.3 <sup>b</sup>	62.4	0–287

\*The *p* value refers to differences among groups (both for sampling areas and age classes), according to Pearson chi-squared test

\*\*Different letters refer to values with significant differences ( $p < 0.05$ ) at the Kruskal–Wallis test



◀ **Fig. 3** Microscopic findings. Several eggs of *Sulcascaaris sulcata* on the surface of esophageal papillae in a loggerhead sea turtle (a). Atrophic gastritis with heterophilic infiltration in the lamina propria and destruction of the mucosal and sub-mucosal surfaces and necrosis (b, c). Cross sections of an adult specimen (arrowhead) of *S. sulcata* (b) and its eggs (b, c) were observed inside the lesions. Bar = 500  $\mu$ m

except for the infection with cardiovascular flukes of Spirorchhiidae where their eggs cause a range of granulomatous reactions in various organs and tissues (Marchiori et al. 2017; Santoro et al. 2017). The only other nematode able to cause gastritis in sea turtles is *Anisakis* sp., which matures as adult forms only in marine mammals (Santoro et al. 2010b; Mattiucci et al. 2018). *Anisakis* infection occurs when sea turtles feed on fish or cephalopods infected with larva L3 of *Anisakis* sp., which are unable to mature to adults in sea turtles, since they represent a dead-end for the parasite (Santoro et al. 2010b). Larvae of the genus *Anisakis* were responsible for a parasitic gastritis observed in 16 and 13 loggerhead sea turtles from the Canary Islands (Spain) (Orós et al. 2004) and southern Italian coast (Santoro et al. 2010b), respectively. In the last case, the *Anisakis* larvae were identified molecularly as belonging to *Anisakis pegreffii* (Santoro et al. 2010b). The migration of *Anisakis* larvae from the lumen of the stomach to the coelomic cavity resulted in ulceration of the gastric mucosa and granulomatous inflammatory reaction in the lamina propria, sub-mucosa, muscular layer, and serosa of the stomach (Orós et al. 2004; Santoro et al. 2010b). Similar lesions were described in two Kemp's ridley turtles from Cape Cod (MA, USA) by Innis et al. (2009).

Differences among the pathological changes by *S. sulcata* and *Anisakis* sp. in sea turtles are obvious as such the parasite stages and sizes (adult and larval forms of *S. sulcata* found in sea turtles are much more longer and larger than *Anisakis* spp.), and its definitive location in the host (Orós et al. 2004; Innis et al. 2009; Santoro et al. 2010b). In marine mammal definitive hosts, gastric ulcers of variable size, number, and depth have been observed in association with adults and larvae of *Anisakis* spp. and other anisakids (Liu and Edward 1971; Bratney and Ni 1992; Abollo et al. 1998; Motta et al. 2008). Parasite-induced ulcers are usually shallow and have their anterior end embedded in the ulcer bed, similar to those observed for *S. sulcata* in loggerhead sea turtles. The mechanisms leading to ulceration of the gastric mucosa by *Anisakis* spp. seem to be linked primarily to the migration of the larval forms through the stomach wall (Moeller 2001). The accumulation of parasitic excretory debris and invasion of the mucosa by bacteria could act as secondary, perpetuating causes of ulcerous gastritis, as well as the direct attachment of the adult nematodes to the mucosa. No migrations through the gastric walls have been described for *S. sulcata* in sea turtles. Nevertheless, the head of the fourth-stage larva of *S. sulcata* (i.e., the infective stage), as well as that of the adult worms,

can be found firmly embedded in gastric mucosa (Berry and Cannon 1981; this study), thus explaining the formation of such ulcerative lesions.

In the Mediterranean Sea, the occurrence of *S. sulcata* in loggerhead sea turtles seems to be limited to its eastern basin and the Tyrrhenian Sea (Sey 1977; Santoro et al. 2010a; Gračan et al. 2012), and no data exists on its intermediate hosts. In Australian and American waters, most of the intermediate hosts of *S. sulcata* are important commercial species of fossorial bivalves living in sandy or muddy bottoms in which the prevalence of infection ranges from 25 to up 64% (Lester et al. 1980; Lichtenfels et al. 1976, 1978; Amato and Amato 1982; Barber et al. 1987; Deardorff 1989).

From the Tyrrhenian Sea, we found infection by *S. sulcata* in loggerhead sea turtles with a CCL  $\geq 57$  cm (larger juveniles and adults), which are known to forage in shallower and coastal waters (Mansfield and Putman 2013) where potential mollusk intermediate hosts should be abundant. All *Sulcascaaris*-positive loggerhead sea turtles from the Tyrrhenian came from the coastal sites located from Castel Volturno to the Naples Gulf where all mussel (*Mytilus galloprovincialis*) farms and wild bivalve beds registered on the Campania coast are concentrated, which in turn could be the intermediate hosts for *S. sulcata*.

Prevalence of infection with *S. sulcata* was significantly higher from the Adriatic Sea (see Table 1). Many small loggerhead sea turtles, both early and large juveniles (CCL  $\geq 33$  cm), were found infected in this area, whereas only bigger individuals (CCL  $\geq 57$  cm) were positive in the Tyrrhenian Sea. The northern area of the Adriatic Sea occupies the flooded seaward extension of the Po Plain and reaches an average bottom depth of about 35 m with sandy or muddy bottoms. It is the most extensive continental shelf of the entire Mediterranean Sea with high macrofaunal density dominated by sedentary invertebrates including a high diversity of fossorial mollusks. This basin hosts one of the largest neritic foraging habitats for loggerhead sea turtles in the Mediterranean (Margaritoulis et al. 2003; Lazar et al. 2004). Demersal stage loggerhead sea turtles are regularly present all over the year in the region, residing for a period of time in the area (Lazar et al. 2004). Small juveniles from Ionian rookeries are also facilitated to reach the northern Adriatic grounds by surface currents passing along the eastern Adriatic coast directing to the north, thus explaining the presence of young individuals with CCL  $< 30$  cm (Lazar et al. 2004). Early use of benthic trophic resources has been already demonstrated in small loggerhead sea turtles (CCL  $> 25$  cm), supporting the existence of a transitional ontogenic stage in which pelagic preys are targeted by the early juvenile turtles together with benthic organisms (Casale et al. 2008).

Lazar et al. (2010) identified 91 taxa of benthic mollusks, including 87 species (37 gastropods, 34 bivalves, and one scaphopod) from the digestive tract of loggerhead sea turtles found in the northern Adriatic Sea. It suggests that mollusks

represent one of the major prey items for loggerhead sea turtles from that basin. On the other hand, Casale et al. (2008) reported that Bivalvia may have a limited importance in the diet of loggerhead sea turtles from the central Mediterranean, with Malacostraca, Gastropoda, and Echinoidea being the most important prey items. Such a high degree of biodiversity could reasonably support a greater abundance of one or more intermediate hosts for *S. sulcata* among the Adriatic benthic communities. The peculiar features of northern Adriatic ecosystem reasonably support a higher probability for the loggerhead sea turtles to get infected by the larvae of *S. sulcata* at an early stage of their life. However, loggerhead sea turtles from both sampling areas were found with high burden of parasites. The increasing trend of *S. sulcata* infection prevalence and abundance along with age (Table 1) suggest that this parasite tends to accumulate in its definitive hosts and this can lead to the development of serious gastric ascariidiosis in individuals with higher burden (Table 2). Studies are currently under way to identify, according to the cycle known experimentally (Berry and Cannon 1981), which mollusk species is acting as an intermediate host for this pathogenic nematode from the Mediterranean basin.

**Acknowledgments** We thank Dr. Lisa Poppi for precious collaboration in getting samples and pictures during the necropsies of the sea turtles from the Adriatic Sea and Giuseppe Di Vincenzo for assembling the figures of the manuscript.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## References

- Abollo E, Lopez A, Gestal C, Benavente P, Pascual S (1998) Long-term recording of gastric ulcers in cetaceans stranded on the Galician (NW Spain) coast. *Dis Aquat Org* 32:71–73
- Amato JFR, Amato SB (1982) *Sulcascaaris sulcata* (Nematoda, Anisakinae) infecting sea scallops being exported from southeastern Brazil. *Arq Univ Fed Rural Rio J* 5(1):61–67
- Barber BJ, Blake NJ, Moyer MA, Rodrick GE (1987) Larval *Sulcascaaris sulcata* from calico scallops, *Argopecten gibbus*, along the southeast coast of the United States. *J Parasitol* 73(3):476–480
- Berry GN, Cannon LRG (1981) The life history of *Sulcascaaris sulcata* (Nematoda: Ascaridoidea), a parasite of marine molluscs and turtles. *Int J Parasitol* 11:43–54
- Bolten AB (1999) Techniques for measuring sea turtles. In: Eckert KL, Bjorndal KA, Abreu-Grobois FA, Donnelly M (eds) Research and management techniques for the conservation of sea turtles. IUCN/SSC Marine Turtle Specialist Group, Washington DC, pp 110–114
- Bratley J, Ni IH (1992) Ascaridoid nematodes from the stomach of harp seals, *Phoca groenlandica*, from Newfoundland and Labrador. *Can J Fish Aquat Sci* 49:956–966
- Casale P, Abbate G, Freggi D, Conte N, Oliverio M, Argano R (2008) Foraging ecology of loggerhead sea turtles *Caretta caretta* in the

- Central Mediterranean Sea: evidence for a relaxed life history model. *Mar Ecol Prog Ser* 372:265–276
- Deardorff TL (1989) Occurrence of larval *Sulcascaris sulcata* (Nematoda: Anisakidae) in the calico scallop, *Argopecten gibbus*, collected along the eastern coast of Florida, with comments on histopathology. *Proc Helminthol Soc Wash* 56(1):82–85
- Gračan R, Buršić M, Mladineo I, Kučinić M, Lazar B, Lacković G (2012) Gastrointestinal helminth community of loggerhead sea turtle *Caretta caretta* in the Adriatic Sea. *Dis Aquat Org* 99(3):227–236
- Greiner EC (2013) Parasites of marine turtles. In: Wyneken J, Lohmann KJ, Musick JA (eds) *The biology of sea turtles*, vol 3. CRC Press, Boca Raton, pp 427–446
- Hartwich G (2009) Ascaridida. In: Anderson RC, Chabaud AG, Willmott S (eds) *Key to the nematode parasites of vertebrates*, archival volume. CABI, Wallingford, pp 309–323
- Innis C, Nyaoko AC, Williams CR 3rd, Dunnigan B, Merigo C, Woodward DL, Weber ES, Frasca S Jr (2009) Pathologic and parasitologic findings of cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*) stranded on Cape Cod, Massachusetts, 2001–2006. *J Wildl Dis* 45(3):594–610
- Lazar B, Margaritoulis D, Tvrtković N (2004) Tag recoveries of loggerhead sea turtles *Caretta caretta* in the eastern Adriatic Sea: implications for conservation. *J Mar Biol Assoc UK* 84:475–480
- Lazar B, Gračan R, Katić J, Zavodnik D, Jaklin A, Tvrtković N (2010) Loggerhead sea turtles (*Caretta caretta*) as bioturbators in neritic habitats: an insight through the analysis of benthic molluscs in the diet. *Mar Ecol* 32:65–74
- Lester RJG, Blair D, Heald D (1980) Nematodes from scallops and turtles from Shark Bay, Western Australia. *Aust J Mar Freshwat Res* 31:713–717
- Lichtenfels JR, Kern FG, Zwerner DE, Bier JW, Madden PA (1976) Anisakid nematodes in shellfish of Atlantic continental shelf of North America. *Trans Am Microsc Soc* 95:265–266
- Lichtenfels JR, Bier JW, Madden PA (1978) Larval anisakid (*Sulcascaris*) nematodes from Atlantic molluscs with marine turtles as definitive hosts. *Trans Am Microsc Soc* 97(2):199–207
- Liu S, Edward A (1971) Gastric ulcers associated with *Contracaecum* spp. (Nematoda: Ascaroidea) in a Steller sea lion and a white pelican. *J Wildl Dis* 7:266–271
- Mansfield KL, Putman NF (2013) Oceanic habits and habitats: *Caretta caretta*. In: Wyneken J, Lohmann KJ, Musick JA (eds) *The biology of sea turtles*, vol 3. CRC Press, Boca Raton, pp 189–210
- Marchiori E, Negrisola E, Cassini R, Garofalo L, Poppi L, Tessarin C, Marcer F (2017) Cardiovascular flukes (Trematoda: Spirorchiidae) in *Caretta caretta* Linnaeus, 1758 from the Mediterranean Sea. *Parasit Vectors* 10(1):467
- Margaritoulis D, Argano R, Baran I, Bentivegna F, Bradai MN, Camiñas JA, Casale P, Demetrio G, Demetropoulos A, Gerosa G (2003) Loggerhead turtles in the Mediterranean Sea: present knowledge and conservation perspectives. In: Bolten AB, Witherington BE (eds) *Loggerhead sea turtles*. Smithsonian Books, Washington DC, pp 175–198
- Mattiucci S, Cipriani P, Levsen A, Paoletti M, Nascetti G (2018) Molecular epidemiology of *Anisakis* and Anisakiasis: an ecological and evolutionary road map. *Adv Parasitol* 99:93–263
- Moeller RB (2001) *Diseases of marine mammals*. California animal health and food safety laboratory system, California, EUA, p.34
- Motta MRA, Pinheiro DCSN, Carvalho VN, Viana DA, Vicente ACP, Iñiguez AM (2008) Gastric lesions associated with the presence of *Anisakis* spp. Dujardin, 1845 (Nematoda: Anisakidae) in cetaceans stranded on the coast of Ceara, Brazil. *Biota Neotrop* 8(2):91–95
- Orós J, Calabuig P, Déniz S (2004) Digestive pathology of sea turtles stranded in the Canary Islands between 1993 and 2001. *Vet Rec* 155(6):169–174
- Santoro M, Badillo FJ, Mattiucci S, Nascetti G, Bentivegna F, Insacco G, Travaglini A, Paoletti M, Kinsella JM, Tomás J, Raga JA, Aznar FJ (2010a) Helminth communities of loggerhead turtles (*Caretta caretta*) from central and western Mediterranean Sea: the importance of host's ontogeny. *Parasitol Int* 59(3):367–375
- Santoro M, Mattiucci S, Paoletti M, Liotta A, degli Uberti B, Galiero G, Nascetti G (2010b) Molecular identification and pathology of *Anisakis pegreffii* (Nematoda: Anisakidae) infection in the Mediterranean loggerhead sea turtle (*Caretta caretta*). *Vet Parasitol* 174(1–2):65–71
- Santoro M, Di Nocera F, Iaccarino D, Lawton SP, Cerrone A, Degli Uberti B, D'Amore M, Affuso A, Hochscheid S, Maffucci F, Galiero G (2017) Pathology and molecular analysis of *Hapalotrema mistroides* (Digenea: Spirorchiidae) infecting a Mediterranean loggerhead turtle *Caretta caretta*. *Dis Aquat Org* 124(2):101–108
- Santoro M, Di Nocera F, Iaccarino D, Cipriani P, Guadano Procesi I, Maffucci F, Hochscheid S, Blanco C, Cerrone A, Galiero G, Nascetti G, Mattiucci S (2018) Helminth parasites of the dwarf sperm whale *Kogia sima* (Cetacea: Kogiidae) from the Mediterranean Sea, with implications on host ecology. *Dis Aquat Org* 129:175–182
- Sey O (1977) Examination of helminth parasites of marine turtles caught along the Egyptian coast. *Acta Zool Hung* 23:387–394
- Sprent JFA (1977) Ascaridoid nematodes of amphibians and reptiles: *Sulcascaris*. *J Helminthol* 51:379–387
- Vicente JJ, Rodrigues HO, Gomes DC, Pinto RM (1993) Nematóides do Brasil. III. Nematóides de répteis. *Rev Bras Zool* 10:19–168
- Werneck MR, Martos Thomazini C, Shigueru Mori E, Gonçalves VT, Gallo BMG, Da Silva RJ (2008) Gastrointestinal helminth parasites of loggerhead turtle *Caretta caretta* Linnaeus 1758 (Testudines, Cheloniidae) in Brazil. *Pan-Am J Aquat Sci* 3(3):351–354

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.