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Abstract. – It has become widely recognized that a large gap exists in the global knowledge of fisheries due to the continued oversight of the small-scale sector. For populations of marine turtles restricted to the eastern Mediterranean, bycatch in small-scale fisheries is a concern. By using North Cyprus as a case study for the region, we used anthropological methods to estimate the magnitude of marine turtle bycatch, while presenting novel information on the marine turtle life stages using the coast and profiling the fishery itself. Our analyses suggest that as many as 1000 turtles may be caught annually by this fishery with an estimated mortality rate of 60%. Trammel nets were the main cause of marine turtle bycatch. Strandings coincided with setting of trammel nets that target siganids (*Siganus luridus* and *Siganus rivulatus*) and the majority of bycatch registered by fishers were caught in these gear types. We demonstrate a relatively simple approach to evaluating marine turtle bycatch, providing information that will allow local authorities and conservation groups to direct further research and possible mitigation measures.

Key Words. – small-scale fisheries; artisanal fisheries; marine turtle; bycatch; trammel net; stranding; Mediterranean

Small-scale fisheries produce more than half of the world's fish catch and support more than 90% of its fishers (FAO 2010). However, their social and economic contributions are underestimated (Zeller et al. 2007), which has led to their marginalization and underinvestment when compared with industrialized fisheries (Peckham et al. 2007; Jacquet and Pauly 2008; McCluskey and Lewison 2008; Read 2008; Alfaro-Shigueto et al. 2010). Because small-scale fishing vessels are highly numerous, diverse, and widely distributed, they are difficult to survey, a major logistical constraint, which has also hindered research (Soykan et al. 2008; Moore et al. 2010; Stewart et al. 2010). In a review by Jacquet and Pauly (2008), small-scale fisheries were described as the best option for sustainable use of fisheries resources. However, negative ecological impacts of small-scale fisheries are increasingly being reported (Shester and Micheli 2011), and some researchers speculate that their bycatch of large threatened marine vertebrates could equal or exceed the contribution of industrialized fisheries (Peckham et al. 2007; Zydelis et al. 2009; Gilman et al. 2010; Mangel et al. 2010; Alfaro-Shigueto et al. 2011). Bycatch of threatened species in small-scale fisheries, therefore, is considered a research priority to quantify and prioritize the threats and to urgently develop and direct mitigation strategies to reduce further population declines (D'Agrosa et al. 2000; Jaramillo-Legorreta et al. 2007; Soykan et al. 2008; Gilman et al. 2010).

Populations of the loggerhead (*Caretta caretta*) and the green turtle (*Chelonia mydas*) are believed to have declined considerably in the Mediterranean due to a multitude of threats, chiefly fisheries mortality and loss of nesting habitat (IUCN 2004; Casale and Margaritoulis 2010). The Mediterranean green turtle was previously regarded by the IUCN Marine Turtle Specialist Group as a critically endangered regional subpopulation (Broderick et al. 2006; Mast et al. 2006; Mrosovsky 2006), largely on account of its genetic isolation and distinctiveness from its global population. A recent global assessment of conservation priorities for marine turtles undertaken by Wallace et al. (2011) recognized the Mediterranean loggerhead and green turtles as regional management units and assessed them as being under high threat and, therefore, in need of targeted conservation action.

The Mediterranean loggerhead turtle population is estimated to contain 2000–3000 nesting females annually, which are found nesting predominantly in Greece, Turkey, Cyprus, and Libya (Broderick et al. 2002; Casale and Margaritoulis 2010). The Mediterranean green turtle

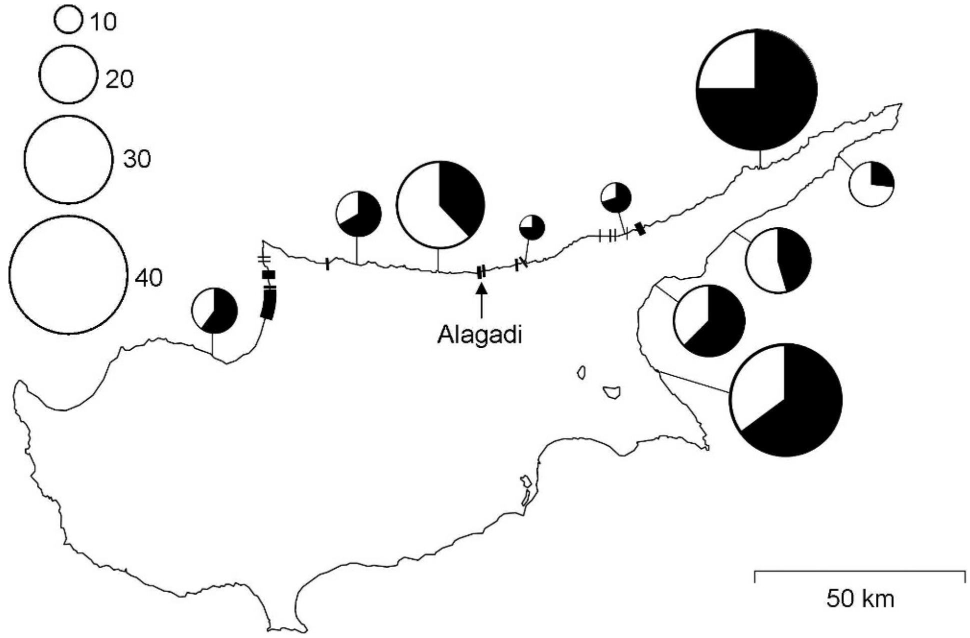

Figure 1. Map of study area in North Cyprus, showing fishing harbor locations, proportions of vessels surveyed, beaches surveyed for carcasses, and Alagadi study beach where size data for nesting females was collected. Black shaded coastline strips represent beaches surveyed for stranded carcasses. Additional carcasses were recorded from public sightings between Gemikonağı and Gazimağusa. Positions of fishing harbors are indicated by pie charts (clockwise from left Gemikonağı, Kayalar and Lapta, Girne, Alagadi and Esentepe, Tatlısu and Kaplıca, Balalan and Yeni Erenköy, Şelones, Kumyalı, Boğaz, Gazimağusa). Area of pie charts represents estimated number of active vessels scaled to the increments on left. Black fractions represent the estimated proportion of active vessels surveyed (Table 1).

population is estimated at 300–400 nesting females annually, and these females are found nesting predominantly in Turkey and Cyprus (Broderick et al. 2002; Casale and Margaritoulis 2010). North Cyprus supports roughly 9% of the Mediterranean's nesting female loggerhead turtles and 28% of the basin's nesting female green turtles, which makes this a significant breeding ground for both species in the region (Broderick et al. 2002; Casale and Margaritoulis 2010).

A recent global analysis of marine turtle bycatch by Wallace et al. (2010) highlighted the Mediterranean as an area where marine turtle populations are particularly threatened by fisheries, which warrants urgent conservation action. Here, an estimated 132,000 marine turtles are captured, and 44,000 die annually as a result of fisheries interactions (Casale 2011). Small-scale fleets in the eastern basin are thought to pose the greatest threat to Mediterranean populations, because they operate close to nesting sites and so may take many breeding adults (Casale 2011). In 1998, marine turtle bycatch was highlighted as a cause for concern in North Cyprus and Turkey (Godley et al. 1998). One decade on, we describe the bycatch problem in greater detail by providing information that will contribute to the establishment of priorities needed for conservation strategies. In this study, our objectives were to a) quantify the threat of small-scale fisheries bycatch to marine turtles in North Cyprus, b) ascertain which turtle life stages are most vulnerable, and c) describe specific aspects of the fishery that might have the greatest impact on affected sea turtle populations.

METHODS

Strandings. — From 1 November 2009 until 31 October 2011, around the coast of North Cyprus, we systematically monitored a series of 16 beaches that total 14 km in length (Fig. 1). During the nesting season, (21 May to 5 October), volunteers patrolled beaches at least once every 3 days as part of a long-term marine turtle monitoring project (Broderick et al. 2002). Outside the nesting season, volunteers patrolled beaches monthly. Volunteers also responded to public sightings across the coast. Upon finding a stranded turtle carcass, notch-to-notch curved carapace length (CCL) was measured, photographs were taken, the carcass was checked for flipper tags, and the state of decomposition and any obvious injuries were noted. After recording, all the carcasses were removed or marked with paint and/or were buried in situ to prevent double recording. Data and images were uploaded by the recording volunteer to the international Sea Turtle Rehabilitation and Necropsy Database (www.seaturtle.org/strand) where they were checked and confirmed by the lead author.

Stranded carcasses were assigned to 3 maturity classes according to adult nesting female data from North Cyprus (Broderick et al. 2003) where female loggerhead turtles ranged from 63 to 87 cm (mean, 73.6 cm) and female green turtles ranged from 77 to 106 cm (mean, 91.5 cm). For their respective species, those carcasses below minimum nesting size were classed as juveniles,

Table 1. Fisher and fishing vessel statistics from government statistics (TRNC 2010) and from our 2011 surveys.

		Authority report 2010			Our survey 2011		
District	Harbor name	Registered fishers	Registered vessels	Active vessels	Total vessels	Active vessels	Vessels surveyed
Lefkoşa	Gemikonağı				30	15	9
	Total	**62**	**60**	**43**	**30**	**15**	**9**
Girne	Kayalar				3	3	2
	Lapta				22	12	8
	Girne				60	29	11
	Esentepe and Alagadi				14	8	6
	Total	**110**	**115**	**73**	**99**	**52**	**27**
Gazimağusa	Tatlısu and Kaplıca				15	10	7
	Balalan				3	3	2
	YeniErenkoy				45	37	28
	Şelones				16	15	4
	Kumyalı				28	22	10
	Boğaz				41	24	15
	Gazimağusa				65	37	24
	Total	**238**	**272**	**184**	**213**	**148**	**90**
		410	**447**	**300**	**342**	**215**	**126**

those between minimum and mean nesting size were classed as potential adults, and those above mean nesting size were classed as adults. However, because size at maturity is expected to vary between sexes (Casale et al. 2005) and genetic origin (Casale et al. 2009), and because these parameters were not recorded for our carcasses, our categorization serves only as relatively coarse guide to the reproductive value of stranded individuals, adults represent a greater loss than juveniles, being better established, less likely to be predated, and closer to their optimum fecundity.

Fisher Surveys to Characterize Fisheries and Bycatch. — During May, June, and July 2010, we carried out a program of 7 workshops in the main fishing harbors in North Cyprus (Fig. 1). Our objective was to gather data on the artisanal fishers by using a written questionnaire (sensu Moore et al. 2010). The fishers completed questionnaires, and organizers answered any queries that they had to provide clarification on specific sections. A total of 91 fishers completed questionnaires in this format. Further one-to-one questionnaire surveys were undertaken in the fishing harbors where an additional 49 fishers were interviewed between May and September 2011 by using the same questionnaire (Fig. 1; Table 1). Qualitative information also was recorded, which resulted from informal discussions held with fishers at workshops and in ports on their boats where they were able to illustrate their gear more clearly.

Vessels were counted in all 14 harbors during July 2011 (Fig. 1; Table 1). Because most vessels were active between dusk and dawn, our counts were made during afternoons, when the majority of vessels were in the harbors. Boats were classified as active or nonactive according to the presence and readiness of gear onboard. These data were compared with government statistics for vessel and fisher numbers (Table 1).

The content of our questionnaires reflected queries developed during small informal preliminary workshops held, before the study, with fisheries cooperative leaders. The fishers were asked to indicate the months during which they were actively fishing and the months during which they had encountered marine turtle bycatch for the previous 12-mo period. They were asked how many turtles they had caught during the previous 12-mo period, and of these, how many had been returned to the sea alive. They were asked to indicate the gear type in which turtles were caught most regularly. In cases in which these gear were gill nets or trammel nets, they were asked to specify the mesh size that most commonly caught turtles. For trammel nets, the mesh size given refers to the inner netting rather than the much larger outer netting.

In a separate questionnaire, the fishers were asked about the configurations of the sets they used for different target catch species and also were asked to list the usual depth, distance of set from shore, set time, haul time, and mesh size for the main target species groups. They were also asked to indicate the months during which these gear were most commonly deployed.

Voluntary Bycatch Reporting. — All the fishers we approached were asked to contact the lead author by telephone on catching a turtle, either dead or alive, so that an inspection could be made and/or details of capture recorded. For most of these reports, we confirmed species and CCL through inspection. The specimens were separated into maturity classes by the same method as described for stranded carcasses. The fishers were asked to explain the gear specifications, target catch, depth of set, and soak time for each turtle caught, and they were asked whether the turtle was dead or alive on hauling.

RESULTS

Strandings. — During the stranding study period (November 2009 to October 2011), 129 marine turtle carcasses were recorded. Of these, 50% were loggerhead turtles and 46% were green turtles, and for 4%, the

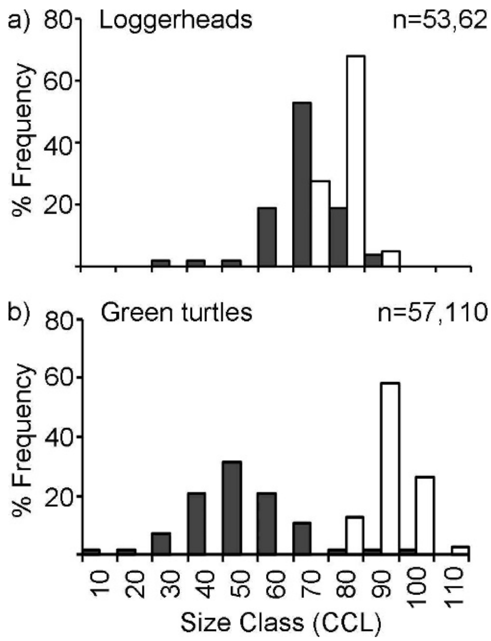

Figure 2. Size frequency histograms for a) loggerhead and b) green turtles in our study area. Shaded boxes represent stranded carcasses, open boxes represent adult nesting females recorded at Alagadi beach (2009–2011). n = number of stranded turtles, number of nesting females.

species was not identified. Size-class frequency data for carcasses were compared with those for breeding adult females recorded at Alagadi nesting beach (Fig. 1) during 2009–2011 (Fig. 2). The mean CCL of loggerhead turtle carcasses was 65 ± 9 cm standard deviation (SD). Thirty-eight percent were juveniles, 47% were potential adults, and 15% were adults. The mean CCL of green turtle carcasses was 47 ± 15 cm SD. Ninety-six percent were juveniles, 2% were potential adults, and 2% were adults. Just 1 carcass was flipper tagged, a female loggerhead turtle that had been tagged during nesting on 12 June 2011 was found dead on 15 July 2011.

Four loggerhead carcasses had clearly been caught on longlines. These 4 carcasses had hooks either in the mouth, through the mouth with line trailing from the cloaca, or in the flipper. All longline gear was typical of local bottom-set longlines that used medium-sized hooks (typically 30-mm total length, 13-mm gape ''j'' hooks [Beverly 2009]). For the remaining carcasses, no cause of death was ascertainable. Temporal patterns of marine turtle carcass reports were largely comparable between species (Fig. 3a, b), with relatively few carcasses reported during winter and increased numbers during summertime, peaking in June.

Fisher Surveys to Characterize Fisheries and By-catch. — The agricultural report of the Turkish Cypriot authorities (TRNC 2010) states that 447 vessels were registered in 2010, of which 300 were active (Table 1). We counted 342 vessels of which 215 were active in July 2011 (Table 1). Because some vessels are said to be brought to the harbor by trailer, the quoted total of 300 active vessels (TRNC 2010) is plausible. Thus, we use this figure as the upper limit and the number of active vessels we counted as the lower limit to estimate a range of 215–300 active vessels. The captains of 126 vessels completed questionnaires (Table 1). Thus, we estimate that, through this study, we acquired data on 42%–59% of the active vessels in our study area with significant contribution from all of the harbors. However, because not every respondent answered every question, our sample sizes varied among questions.

All of the vessels registered with North Cyprus authorities are less than 12 m long, and no vessels are permitted to use nonstatic gear. No industrialized vessels or nonstatic gear were observed in ports. Forty-four percent of captains (n = 124) fish throughout the year and more than 80% are active from April through October (Fig. 3c). Peak activity is during May when 95% of those surveyed claimed to be active. Eighty-seven percent regularly used bottom-set nets (gill nets and/or trammel nets), 68% regularly used longlines, and 55% regularly use both (n = 101). The most common mesh size used by the fishers for bottom-set nets was 18 mm, with a range of other mesh sizes between 24 and 32 mm also commonly used (Fig. 4a). Mesh sizes larger that 24 mm were soaked for markedly longer periods than mesh sizes smaller than 24 mm (Fig. 4b). During discussions, the fishers stated the reason for this was that large fish are able to survive entanglement for longer periods, whereas small fish die quickly and so spoil during longer soaks.

Temporal data for the main bottom-set net fisheries are presented in Fig. 5. Siganids (*Siganus luridus* and *Siganus rivulatus*) (Fig. 5a) are fished throughout the year but most intensively during June to August. Bogue (*Boops boops*) is also fished most heavily during the summer months (Fig. 5b). Picarels (*Spicara smaris* and *Spicara maena*) have a relatively narrow fishing season, from February to May (Fig. 5c), and red mullets (*Mullus surmuletus* and *Mullus barbatus barbatus*) are fished relatively heavily and consistently throughout the year, particularly from March to April (Fig. 5d). Details of the depth, distance from shore, soak time, and mesh sizes used for the 4 most commonly fished groups are presented in Table 2.

In discussions with the fishers in the harbors, they indicated that nets that target red mullets and siganids are always trammel nets and that single-panel gill nets were used for picarels and bogue. The outer-netting mesh size for trammel nets is determined by multiplying the chosen inner-mesh size by a factor of 4–5. All nets seen were made from monofilament or multistrand nylon materials, and both material types were seen for trammel nets and gill nets. Longlines were organized and stowed around baskets that would typically stow 200–300 hooks. The fishers indicated that all the longlines used were set on the benthos to target groupers and porgies (Epinephelinae and Sparidae) and that baskets would be set and hauled within 1 fishing trip, often while bottom-set nets were being

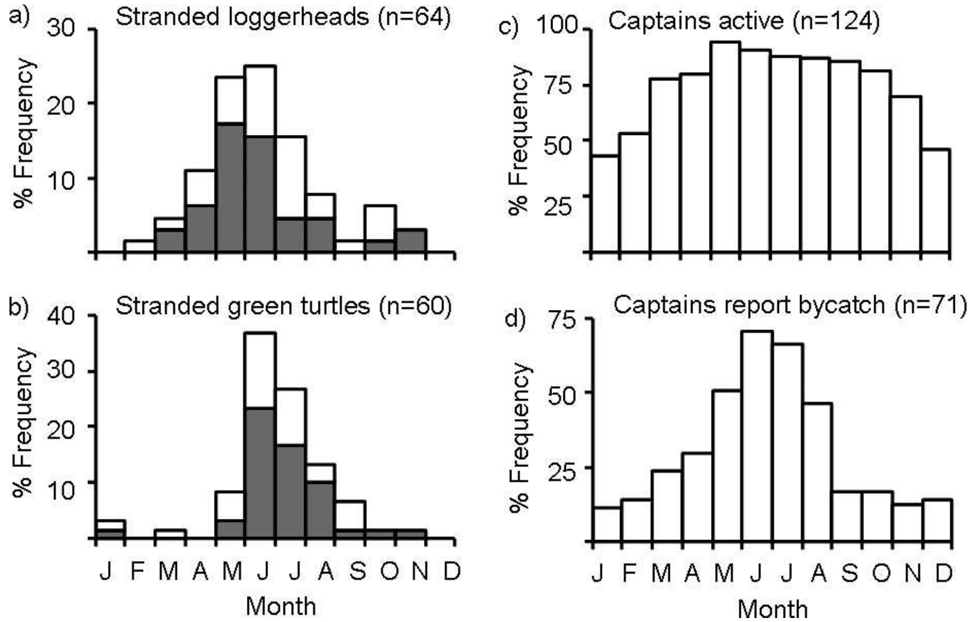

Figure 3. Temporal distribution of stranded a) loggerhead and b) green turtle carcasses. Shaded boxes show carcasses recorded on year-round study beaches, open boxes indicate carcasses recorded opportunistically and from public calls. Months of year during which captains stated in questionnaires that they c) actively fished and d) caught turtles.

soaked. Some fishers stated that they switched to only longlines when net catches were low or when net-and-catch damages associated with depredation by dolphins were high. Two fishers in our study explained that surface longlines that target swordfish were occasionally used by a few of the fishers in North Cyprus, although these were not detailed in our questionnaire results. Sixty-six percent of captains ($n = 117$) claimed to have caught $\geq$ 1 turtles during the previous 12 mo. Of these, the median number of turtles caught was 5.5 (interquartile range [IQR], 3–12.5) with a median of 4 (IQR, 2–10) (73%) of these released alive. Among the remaining 34% of captains, it was not possible to separate true-negative results from false-negative results, so we assumed in our extrapolation that they caught no turtles. We thus extrapolated the median annual bycatch of 5.5 turtles per year to 66% (the proportion of or sample of captains who responded affirmatively) of the estimated 215–300 active vessels (i.e., 142–198 vessels) to estimate a range of 780–1089 turtles. Thus, it is likely that on the order of 700–1100 turtles are captured annually in North Cyprus.

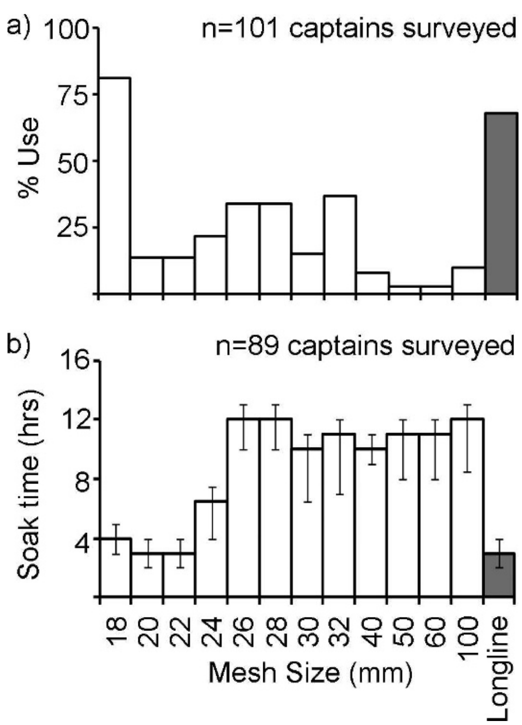

Figure 4. a) Percentage of captains using and b) soak time for various mesh sizes we recorded. Meshes < 32 mm are in 2-mm bins, meshes > 32 mm are in 10-mm bins. Shaded boxes represent bottom-set longlines. Error bars denote interquartile range.

Most fishers indicated that their marine turtle bycatch was highest during the summer months, specifically May–August (Fig. 3d). Of 77 fishers who provided information on gear associated with bycatch, 94% confirmed bottom-set nets and 14% confirmed longlines. Of those fishers who claimed to have caught marine turtles in bottom-set nets, the median mesh size indicated was 28 mm (IQR, 20–32; range, 18–100; $n = 28$).

Voluntary Bycatch Reporting. — From June 2010 to July 2012, 8 loggerhead turtles and 20 green turtles were registered with the lead author by fishers (Tables 3 and 4). Registered loggerheads were caught at a median depth of 20 m in bottom-set trammel nets (62.5%) and on bottom-set longlines (37.5%). The majority of trammel nets were targeting siganids, whereas all other trammel nets and longlines targeted groupers and porgies. The mean CCL of loggerheads was 70.3 ± 13.7 cm SD, and the majority

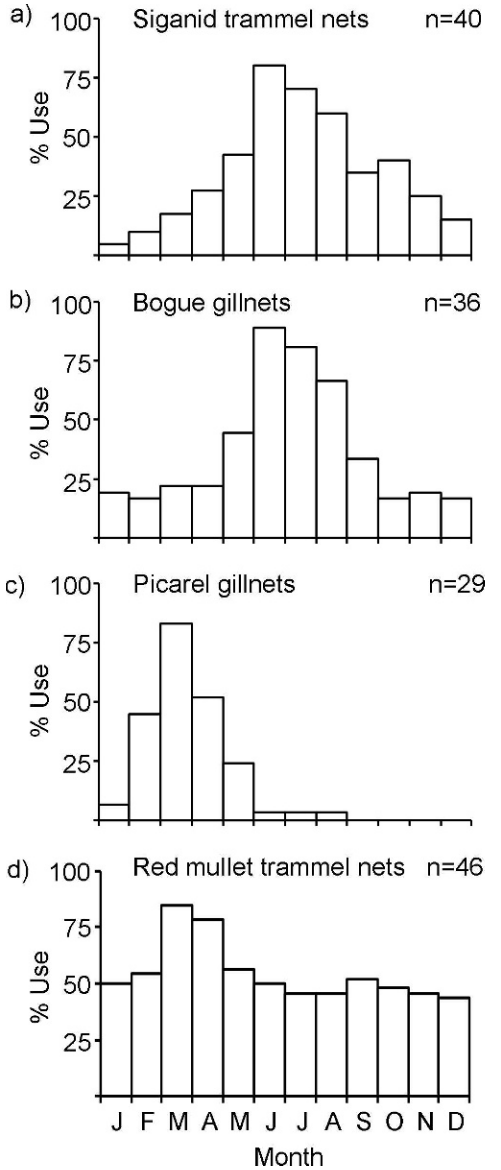

Figure 5. Percentage of captains who used bottom-set nets by month for a) siganids (*Siganus luridus* and *Siganus rivulatus*), b) bogue (*Boops boops*), c) picarels (*Spicara smaris* and *Spicara maena*) and d) red mullets (*Mullus* spp.).

(75%) were potential adults. Three of 5 loggerheads caught in trammel nets died, which equated to a minimum mortality rate of 60% for loggerhead turtles caught in these gear. One turtle was dead on hauling, and 2 died on inspection between 30 min to 1 hr after hauling. One surviving turtle was released alive by the fisher on hauling, and one was deemed fit to be released on inspection. Of 3 loggerheads caught on longlines, 2 were released alive by the fisher on hauling. Both were released with hooks in the mouth and throat, and with monofilament snoods estimated at 30 and 60 cm, respectively, trailing from the mouth. Another was deemed fit for release on inspection after a hook was removed from the rear flipper.

Green turtles were all caught in bottom-set trammel nets at a median depth of 14 m, the majority (89%) of

Table 2. Depth, distance from shore, soak time, and mesh size described by fishers for siganid (*Siganus luridus* and *Siganus rivulatus*) trammel nets, bogue (*Boops boops*) gill nets, picarel (*Spicara smaris* and *Spicara meana*) gill nets, and red mullet (*Mullus* spp.) trammel nets.[a]

Target catch	Depth (m)				Distance from shore (m)				Soak time (hrs)				Mesh size (mm^2)			
	Median	IQR	Range	*n*	Median	IQR	Range	*n*	Median	IQR	Range	*n*	Median	IQR	Range	*n*
Siganids	15	12–20	5–42	47	113	50–225	10–600	41	11	9–12	3–15	48	28	28–30	18–33	60
Bogue	41	40–45	10–95	39	400	238–525	50–4000	32	3	3–5	1–7	41	18	18–19	18–25	56
Red mullets	41	38–68	10–180	62	500	238–813	40–5000	52	4	3–5	1–17	68	18	18–19	18–23	85
Picarels	40	40–41	38–43	7	500	275–500	100–4000	7	3	1–3	1–5	8	18	18–18	16–21	24

[a] IQR = interquartile range.

Table 3. Details of registered bycatch for loggerhead turtles between June 2010 and July 2012.[a]

Harbor	Date mo/yr	Fisher no.	Inspection made?	Maturity class	CCL (cm)	State on hauling	Fate	Target	Gear type	Soak (hrs)	Mesh (mm)	Depth (m)
Lapta	Jun/10	10	Yes	PA	63.5	Alive	DOI	Porgies/groupers	Trammel	12	32	
Kaplıca	Jul/10	2	Yes	PA	71	Alive	ROI	Siganids	Trammel		32	20
Lapta	Nov/11	10	By photo	J	60	Alive	ROH	Porgies/groupers	Trammel	12	32	
Gazimağusa	Jun/12	6	Yes	PA	65	Alive	DOI	Siganids	Trammel	4	32	25
Gazimağusa	Jul/12	4	By photo	PA	65	Dead	DOH	Siganids	Trammel	10	26	20
Boğaz	Jul/12	13	No	PA	70	Alive	ROH_E	Porgies/groupers	Longline	8		19
Boğaz	Jul/12	13	No	A	103	Alive	ROH_E	Porgies/groupers	Longline	13		27
Boğaz	Jul/12	13	Yes	PA	65	Alive	ROI	Porgies/groupers	Longline	11		18
n					8							
Mean					70.3							
SD					13.7							
Range					60–103							
n										7	5	6
Median										11	32	20
IQR										9–12	30–32	19–25
Range										4–13	26–32	18–27

[a] Where turtles were released on inspection they were deemed by the lead author to be fit for release. J = juvenile; PA = potential adult; A = adult; CCL = curved carapace length; DOI = dead on inspection; ROI = released on inspection; ROH = released on hauling; DOH = dead on hauling; ROH_E = released with entanglement on hauling; SD = standard deviation; IQR = interquartile range.

which targeted siganids (Table 4). The mean CCL of these was 36.9 ± 12.4 cm SD, and all were juveniles. Twelve were dead on capture, which equated to a minimum mortality rate of 60% for green turtles caught in trammel nets. Five were released on inspection, one of which was not able to dive. Three were released alive by the fisher on hauling.

DISCUSSION

Through a combination of ecological and anthropological data collection methods, this study provides a current assessment of marine turtle bycatch in North Cyprus. We also presented the first detailed descriptions of the commonly used gear and their relative threats to marine turtles, which are crucial pieces of information when considering priority gear and areas for mitigation. We provide the first insights into the importance of North Cyprus's coastal marine habitats for small-to-medium–sized juvenile green turtles and large juvenile loggerhead turtles, which revealed an interesting discrepancy in vertical habitat use, with the former apparently occupying shallower benthic waters. Although North Cyprus is a well-documented nesting site, no literature describes foraging habitats, which clearly must exist to support these size classes.

We presented circumstantial evidence from multiple sources, which indicate that there is a high likelihood that many of our stranded carcasses were of turtles that died through entanglements in or interactions with bottom-set trammel-net gear, specifically those that targeted siganids. Temporal patterns of siganid fishing mirror temporal stranding patterns and fisher descriptions of marine turtle bycatch seasonality (Fig. 3). Fishers themselves indicated in questionnaires that most turtles were caught in bottom-set nets of mesh sizes typical of those used to target siganids. Most compelling is that the majority of turtles registered with us were caught in these gear and that size frequencies were fairly consistent between stranded carcasses and registered bycatch (Fig. 2; Tables 3 and 4).

Some of the characteristics that we described for siganid trammel nets may make them more dangerous to turtles than do other gear. For example, siganid nets are set in much shallower water and closer to shore than other nets (Table 2). They are thus more likely to overlap with known marine turtle habitats. Results of behavioral studies have shown that both foraging (Broderick et al. 2007; McClellan and Read 2009) and nesting (Hochscheid et al. 1999; Hays et al. 2002; Houghton et al. 2002; Schofield et al. 2009; Fossette et al. 2012) loggerhead and green turtles typically inhabit shallow coastal habitats. Although behavioral studies of juvenile turtles are lacking for North Cyprus, our bycatch data suggest that they also occupy shallow benthic habitats. Mesh size also may play an important role in entanglement, particularly because siganid nets are always trammel nets with large outer-panel mesh

Table 4. Details of registered bycatch for green turtles between June 2010 and July 2012 (see Table 3 for definition of abbreviations).[a]

Harbor	Date mo/yr	Fisher no.	Inspection made?	Maturity class	CCL (cm)	State on hauling	Fate	Target	Gear type	Soak (hrs)	Mesh (mm)	Depth (m)
Gemikonağı	Jun/10	0	Yes	J	60	Alive	ROI		Trammel			
Gemikonağı	Jun/10	1	Yes	J	27	Dead	DOH		Trammel			
Esentepe	Jun/11	3	Yes	J	27	Alive	ROI	Siganids	Trammel		28	9
Lapta	Apr/12	7	Yes	J	39	Dead	DOH	Siganids	Trammel		32	14
Lapta	Apr/12	7	Yes	J	36	Dead	DOH	Siganids	Trammel		32	14
Lapta	Apr/12	7	Yes	J	45	Dead	DOH	Siganids	Trammel		32	14
Tatlısu	May/12	3	Yes	J	26	Dead	DOH	Siganids	Trammel	13	32	10
Lapta	May/12	11	Yes	J	30.4	Dead	DOH	Siganids	Trammel		32	
Kaplıca	Jun/12	2	Yes	J	33.5	Alive	ROI	Siganids	Trammel	5	32	20
Lapta	Jun/12	11	Yes	J	27.4	Dead	DOH	Siganids	Trammel		32	
Lapta	Jun/12	11	Yes	J	31	Dead	DOH	Siganids	Trammel		32	
Lapta	Jun/12	11	Yes	J	26.9	Dead	DOH	Siganids	Trammel		32	
Lapta	Jun/12	11	Yes	J	28	Dead	DOH	Siganids	Trammel		32	
Gazimağusa	Jun/12	4	No	J	63	Alive	ROH	Siganids	Trammel	12	24	14.5
Lapta	Jun/12	7	Yes	J	33.8	Dead	DOH	Red mullets	Trammel	3	18	19
Y. Erenköy	Jun/12	8	Yes	J	29	Alive	ROI	Siganids	Trammel	11		8.5
Boğaz	Jun/12	13	No	J	58	Alive	ROH	Siganids	Trammel	3	20	3
Lapta	Jul/12	10	Yes	J	27	Alive	ROI	Porgies/groupers	Trammel	12	32	38
Boğaz	Jul/12	14	No	J	55	Alive	ROH	Siganids	Trammel	4	28–32	6.5
Boğaz	Jul/12	14	No	J	34	Dead	DOH	Siganids	Trammel	4	28–32	6.5
n					20							
Mean					36.9							
SD					12.4							
Range					26–63							
n										9	17	13
Median										5	32	14
IQR										4–12	30–32	9–15
Range										3–13	18–32	3–38

[a] Where turtles were released on inspection, they were deemed by the lead author to be fit for release; however, one individual released was unable to dive.

sizes. Also, because mesh size seems to regulate soak time (Fig. 4), the probability of turtles encountering siganid nets and being held beneath the surface for long durations is probably greater than for other small-mesh gear. Further research might reveal useful associations between mesh size and size class of turtles taken as bycatch in this type of fishing gear.

Although fishers claimed in questionnaires that most turtles were released alive back to the sea alive, the likelihood of survival of these individuals is uncertain because a number of postrelease turtle mortalities are likely to occur (Lutcavage and Lutz 1991). Recent research in similar fisheries of North Carolina (USA) suggested that up to 30% of turtles that survived gill-net entanglement died after release (Snoddy and Southwood Williard, 2010). The reported bycatch data that we presented include 2 loggerhead turtles that were alive on hauling but that subsequently died on inspection and 2 loggerhead turtles caught on longlines that were released at sea with entanglements that likely caused their death (Chaloupka et al. 2004). Because these ''doomed'' turtles would have been included in our questionnaire-derived estimates of numbers returned to the sea alive, our questionnaire-derived mortality rates are clearly underestimates. Bycatch reported by the fishers show a minimum mortality rate of 60% for both species when entangled in trammel nets, and analysis of data for longlines suggests a similar postrelease mortality rate when fishers do not use best practices for disentanglement. Therefore, of the 800–1100 turtles that we estimate are caught annually, between 480 and 660 are probably killed. Although there are uncertainties in our annual bycatch extrapolation (e.g., the true number of active vessels), we are confident that the magnitude of our estimates is correct. Furthermore, these estimates should be considered conservative because false-negative results (when fishers chose not to disclose their bycatch estimates) were not included in our capture extrapolation and because the fate of released turtles was not fully quantified.

One weakness of our strandings survey was that we were unable to match our spatial coverage of the fishery. Stranded carcasses from areas that surround our survey beaches are therefore better represented than other areas where vessels are greater in number.

As a well-documented nesting site for both loggerhead and green turtles, one might expect to see adults of both species as incidental bycatch in North Cyprus, particularly because fishing effort is highest just before the onset of and throughout the nesting season. Nesting data for adult green turtle females show that nesting female numbers in North Cyprus during 2010 and 2011 were among the highest in 19 seasons (Marine Turtle Research Group, unpubl. data, 2010, 2011); however few adult carcasses stranded. Because they apparently are present in coastal waters at the same time, differences in the habitat use patterns of adult and juvenile green turtles relative to fishing gear in use might render juveniles more susceptible to gill-net entanglement than adults. There is some evidence among behavioral and dietary studies to support this. Of 10 nesting female and 1 breeding male green turtle tracked from Alagadi, none remained in Cypriot waters after the nesting season (Broderick et al. 2007; Wright et al. 2012). Three further studies undertaken at Alagadi have shown that, during the nesting season, gravid green turtles spend the majority of their time in waters $\leq$ 5 m deep, which would put them above the depth range of the shallowest set gill nets used by fishers in North Cyprus, including siganid trammel nets (Hochscheid et al. 1999; Hays et al. 2002; Fuller et al. 2009a). Green turtles are thought to progress from pelagic zooplankton foraging to omnivorous neritic feeding, becoming increasing herbivorous as they grow older but maintaining a mostly omnivorous diet throughout their juvenile lives (Cardona et al. 2009). This is supported by recent work that used stable isotope analysis from turtles of the eastern Mediterranean, including Cyprus (Cardona et al. 2010). In one harbor during 2010, 2011, and 2012, we recorded 2 juvenile green turtles being hand-fed discards by fishers (R. Snape, *per. obs.*). Juvenile green turtles are known to scavenge discards elsewhere (Cardona et al. 2009), and this behavior might lead them to depredating from static fishing gear, which makes them more vulnerable to entanglement than their adult counterparts.

A paucity of lower size classes of loggerheads has previously been noted in North Cyprus waters (Godley et al. 1998), and this is substantiated in our results, in which very few loggerheads encountered were $<$ 50 cm CCL. In Greece, adult male and female loggerheads tracked up to a month before and during nesting primarily used shallows $\leq$ 5 m deep within 500 m of the shore (Schofield et al. 2009; Fossette et al. 2012). Time depth recorder studies at Alagadi showed nesting female loggerhead turtles to use benthic waters $<$ 20 m deep (Houghton et al. 2002), with significant periods spent within depths at which siganid trammel nets might be encountered.

To address conservation concerns through the development and implementation of mitigation strategies, it is important to know that numbers of caught turtles are indeed large enough to significantly impact specific populations and hence merit investment. At the population level, we assume that our bycatch turtles are all from Mediterranean breeding stock. But how do we decide which species is most at risk and so where to further prioritize research? Loggerhead turtles in the basin are more widespread and greater in number, and are reported to be under less threat and at lower risk than green turtles (Wallace et al. 2011). Analysis of our data suggests that perhaps fewer loggerheads are taken in North Cyprus waters than are green turtles. Therefore, one might conclude that the most immediate concern would be the bycatch of green turtles. But when the size (CCL) of our samples are taken into account, the net fisheries impact on the loggerhead population may rival or exceed the impact on the green turtle population in terms of its overall deleterious consequences because the loggerheads we recorded were likely closer to their optimum fecundity and better established than green turtles, their relative value to that population, therefore, being greater. Although we did not calculate true reproductive values for the specimens we encountered, as per Wallace et al. (2008), such an approach might be useful in further prioritizing conservation action between loggerhead and green turtle populations. At the rookery level, adult and juvenile loggerheads and juvenile green turtles from the relatively large rookeries of both species in Turkey or elsewhere in the Mediterranean may migrate to North Cyprus waters to forage and make up a proportion of those turtles impacted here. A haplotype identification program for stranded and caught turtles to ascertain which rookeries are most impacted by the North Cyprus fishery might further aid conservation decisions.

Still, implementation of mitigation measures in small-scale fisheries presents a great challenge because fishers naturally prioritize their own needs above the requirements of governing bodies or the requests of conservation groups. Regulation is difficult to achieve in small-scale fisheries as vessels are too numerous for authorities to manage. A recent study, however, has shown some success in persuading fishers to adopt bycatch reduction technologies where a positive human context has been created and where fishers have actively participated in research (Piovano et al. 2012). Also, although the structures of small-scale fisheries can hinder our understanding of them, their social systems have been used to promote cooperative management between governments and fishers (Campbell et al. 2009). Many of the fishers we approached in our study were concerned about marine turtle bycatch and were saddened when they had found dead turtles in their nets. The majority believe that turtles depredate fish from their nets, which causes significant financial losses and so would likely be open to experimenting with and using methods that reduce these incidents. Fishers certainly became more cooperative with repeated contacts, particularly when their efforts to report turtles were covered favorably in local media.

In terms of reducing marine turtle bycatch at a local level, this study has allowed us to establish specific priorities for mitigation in North Cyprus. Of the gear we studied, it would appear that further detailed scrutiny of the siganid fishery could yield the greatest dividend in reducing bycatch of either population. Onboard observers could now be used to compare marine turtle bycatch in siganid trammel net sets with bycatch in sets for other target catch to ground-truth our survey results. A number of marine turtle bycatch reduction strategies have been tested for static gill nets (Gilman et al. 2010), i.e., low-profile nets and illuminated nets (Wang et al. 2010), which could be tested in North Cyprus. Certain expenses, including net materials, are subsidized by the North Cyprus authorities, so governance could be implemented through a top-down solution wherein governmental practices impact the magnitude of turtle bycatch, i.e., those gear that are shown not to impact turtles are preferentially subsidized. Potential impacts of such strategies must first be assessed from a wider ecological perspective. For example, in the Mediterranean, *S. rivulatus* and *S. luridus* are both very successful lessepsian invader species (Hassan et al. 2003) and seagrass (*Posidonia oceana*) is an important part of their diet (Shakman et al. 2009), so reduction in siganid fishing effort in North Cyprus could increase seagrass grazing pressure. Seagrass meadows constitute an important neritic habitat for North Cyprus (Fuller et al. 2009b, 2009c, 2010a, 2010b) and are thought to be declining globally (Gonzalez-Correa et al. 2007).

In the wider eastern Mediterranean, a regional program of local studies is required to assess specific fishery characteristics at scales used in this study. We recommend that the best way to achieve this would be through a combination of anthropological surveys similar to those outlined here and the establishment of voluntary, fisher-based bycatch reporting schemes and long-term marine turtle strandings networks. Results of such studies would enable identification of the highest impact fishing gear with a high degree of resolution. Only when specific aspects of individual fisheries are examined can we then test and implement the most appropriate and effective mitigation techniques to reduce marine turtle bycatch.

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