Putting Longline Bycatch of Sea Turtles into Perspective

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Abstract: *Although some sea turtle populations are showing encouraging signs of recovery, others continue to decline. Reversing population declines requires an understanding of the primary factor(s) that underlie this persistent demographic trend. The list of putative factors includes direct turtle and egg harvest, egg predation, loss or degradation of nesting beach habitat, fisheries bycatch, pollution, and large-scale changes in oceanographic conditions and nutrient availability. Recently, fisheries bycatch, in particular bycatch from longline fisheries, has received increased attention and has been proposed as a primary source of turtle mortality. We reviewed the existing data on the relative impact of longline bycatch on sea turtle populations. Although bycatch rates from individual longline vessels are extremely low, the amount of gear deployed by longline vessels suggests that cumulative bycatch of turtles from older age classes is substantial. Current estimates suggest that even if pelagic longlines are not the largest single source of fisheries-related mortality, longline bycatch is high enough to warrant management actions in all fleets that encounter sea turtles. Nevertheless, preliminary data also suggest that bycatch from gillnets and trawl fisheries is equally high or higher than longline bycatch with far higher mortality rates. Until gillnet and trawl fisheries are subject to the same level of scrutiny given to pelagic longlines, our understanding of the overall impact of fisheries bycatch on vulnerable sea turtle populations will be incomplete.*

Keywords: bycatch, driftnet, fisheries, gillnet, incidental take, longline, sea turtle, trawl

Perspectivas de la Captura Incidental de Tortugas Marinas en Palangres

Resumen: *Aunque algunas poblaciones de tortugas marinas están mostrando señales alentadoras de recuperación, otras continúan declinando. La reversión de las declinaciones requiere del entendimiento del (los) factor(es) primarios subyacente(s) en esta tendencia demográfica persistente. La lista de factores putativos incluye la cosecha directa de tortugas y huevos, depredación de huevos, pérdida o degradación de playas para anidación, captura incidental de pesquerías, contaminación y cambios a gran escala en las condiciones oceanográficas y la disponibilidad de nutrientes. Recientemente, la captura incidental de pesquerías, en particular la de pesquerías con palangre, ha recibido mayor atención y ha sido propuesta como la causa principal de mortalidad de tortugas. Revisamos los datos existentes sobre el impacto relativo de la captura incidental de palangres sobre poblaciones de tortugas. Aunque las tasas de captura incidental por embarcaciones individuales son extremadamente bajas, la cantidad de equipo desplegado por las embarcaciones sugiere que la captura incidental acumulativa de tortugas de clases de edad más viejas es sustancial. Estimaciones actuales sugieren que aun si los palangres pelágicos no son la mayor causa individual de la mortalidad relacionada con pesquerías, la captura incidental en palangres es lo suficientemente alta como para justificar acciones de manejo en todas las flotas que encuentran tortugas marinas. Sin embargo, los datos preliminares también sugieren que la captura incidental por pesquerías de redes agalleras y de arrastre es igual o más alta que la captura incidental en palangres y sus tasas de mortalidad son mucho más altas. Nuestro entendimiento del impacto global de la captura incidental de pesquerías sobre poblaciones vulnerables de tortugas marinas será*

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incompleto hasta que las pesquerías de redes agalleras y de arrastre estén sujetas al mismo nivel de escrutinio que los palangres pelágicos.

Palabras Clave: captura incidental, captura secundaria, palangre, pesquerías, red agallera, red de arrastre, red de enmalle de deriva, tortuga marina

Introduction

Whereas some marine turtle populations are showing encouraging signs of recovery (Bjorndal et al. 1999; Balazs & Chaloupka 2004; Troeng & Rankin 2005; Heppell et al. 2005*a*), other populations continue to decline. Leatherbacks (*Dermochelys coriacea*) in the Pacific have declined more than 95% in the last 25 years (Spotila et al. 2000) and Pacific loggerheads (*Caretta caretta*) have undergone at least an 80% decline in nesting females over the last 20 years (Kamezaki et al. 2003; Limpus & Limpus 2003). Although the cause of particular declines has not been unequivocally identified, the putative list of threats includes direct turtle and egg harvest, egg predation by non-native animals, nesting-beach habitat degradation or loss, fisheries bycatch (incidental take), and pollution (Lutcavage et al. 1997; Bugoni et al. 2001; Stewart & Wyneken 2004). Other hypotheses relate to large-scale changes in oceanographic conditions and nutrient availability (Solow et al. 2002; Wallace et al. 2004; Saba et al. 2006). Ideally, to identify which anthropogenic (and thus potentially manageable) factors are exerting the greatest influence on sea turtle populations, one would compare the relative impact of these factors on the vital rates (including fecundity, survival, and growth rates) of imperiled populations. Unfortunately, lack of data on the large-scale effects of anthropogenic factors, basic turtle demography, and accurate population estimates make this assessment difficult. Without such specific data, we must draw inferences based on the relative magnitude of the threats, the life stages affected, life-history theory, and population dynamics of better-understood, but long-lived, species (Heppell et al. 2005*b*).

Why Focus on Longline Fisheries?

The impact of fisheries bycatch, particularly that in pelagic longline fisheries, has been under intense scrutiny in the United States and elsewhere. The current focus on pelagic longline bycatch results, in part, from this fisheries' tendency to affect older age classes. Sea turtle population growth is most sensitive to disturbances that kill individuals from older age classes because these individuals have higher per capita reproductive values (Crouse et al. 1987; Heppell 1998). Reproductive value, the number of offspring a member of a given age group can produce between any specific age and their death, tends to be highest at the onset of reproductive maturity (Fisher 1930). Elasticity analyses of population growth rates across turtle species consistently show that these rates depend strongly on survival of turtles nearing and reaching sexual maturity (i.e., large juveniles, subadults, and older [Heppell 1998]). Data collected on loggerhead bycatch from pelagic longline vessels in several ocean regions provide conclusive evidence that these critical older age classes are taken by both small and large-scale longline vessels (Table 1). Although far less body size data are available for other sea turtle species, existing information suggests a similar pattern for green (*Chelonia mydas*) and leatherback turtles (Hernandez & Flores 2003; Largacha et al. 2005; NMFS 2005).

The intense scrutiny of longline fisheries also results, in part, from the availability of data. Unlike many fishing gears, substantial data are available on pelagic longline fisheries because they target highly valuable tuna and billfish in international waters. To promote sustainability and to manage fishing effort and catch of this shared resource, pelagic longline fisheries are overseen by regional fishing management organizations (RFMOs, e.g., the International Commission for the Conservation of Atlantic Tuna [ICCAT]). The RFMOs release information on catch and for some organizations, this information is spatially explicit and fleet specific. In addition to data on pelagic longline fishing effort, some countries deploy independent observers on board fishing vessels to report catches of target species. Recently, these observers also have begun recording incidental take of sea turtles and other threatened species. This means that relative to other fisheries, large-scale pelagic longline fisheries are data rich and turtle/gear interactions are being observed directly.

The Impact of Longline Fisheries

Since 1995 reports of sea turtle bycatch in longline fisheries have been published or released from 19 different fleets from 16 different nations. These reports provide some information on how frequently turtle bycatch occurs. Unfortunately, direct comparisons among reported bycatch rates are not straightforward. Each rate is based on a different sample size (number of hooks observed), fleets differ in fishing gear and practices, and encounters are strongly influenced by gear configuration, which differs by target species (e.g., shallow sets that target swordfish tend to catch far more turtles than deep sets that target tuna [NMFS 2004]). Bycatch rates vary substantially in space and time (Fig. 1), in part because of different gear configurations and fishing practices but also because of turtle and fishing vessel movement. Even among four different fleets deploying tuna (deep) sets in the Pacific, maximum bycatch rates of leatherbacks for each fleet

Table 1. Average size of loggerhead turtles caught by pelagic longlines as measured by curved carapace length.[a]

Oceanic region and target species	*Mean (cm)[b]*	*Source*
Mediterranean		
bluefin	64 (42–80)	Camiñas & Valeiras in Laurent et al. 2001
swordfish	56 (37–75)	Kapantagakis in Laurent et al. 2001
	45 (19–100)	De Metrio & Deflorio in Laurent et al. 2001
	57 (32–79)	Camiñas & Valeiras in Laurent et al. 2001
albacore	40 (22–69)	Camiñas & Valeiras in Laurent et al. 2001
	37 (20–61)	De Metrio & Deflorio in Laurent et al. 2001
Atlantic		
swordfish	58 (57–67)	Pinedo & Polacheck 2004
	53 (35–65)	Bolten & Bjorndal 2005
	74 (36–83)	NMFS 2005
mixed	58 (46–73)	Kotas et al. 2004
Pacific		
bigeye	57 (30–80)	Lagarcha et al. 2005
mixed	65 (51–91)	NMFS 2005

[a]*This table represents all reported size data for loggerheads caught by longlines, and data span both large- and small-scale fishing boats.*
[b]*Minimum and maximum values in parentheses. Turtles in the 50- to 90-cm size class are believed to include large juveniles and subadults. Turtles larger than 90 cm are typically classified as adults (Bjorndal et al. 2001; TEWG 2000).*

ranged from 30–60% of the highest overall rate (AFFA 2001; CSLP 2001; SPREP 2001; NMFS 2005).

Despite the variability in bycatch, two consistent patterns emerge. First, only a relatively small proportion of the turtles hooked or entangled in longlines die on the line prior to retrieval (estimates range from 4 to 27%, in Aguilar et al. 1995; McCracken 2000; NMFS 2001; Camiñas 2004). Although mortality rate while the gear is in the water is low, some captured turtles can be killed intentionally for consumption or unintentionally by poor handling and release practices (Chan & Hock-Chark 1996; Watson et al. 2005). The second common pattern is that sea turtle bycatch is relatively rare (i.e., bycatch data sets typically have many zeros punctuated by counts of hooked or entangled turtles). Although any one longline vessel has very few (or even no) encounters with turtles, and individual longliners may perceive that they have little or no effect on sea turtles, the fact that there are billions of pelagic longline hooks in the water every year suggests that cumulative effect of longline bycatch may be substantial (Lewison et al. 2004).

Applying these rates to accurately estimate the number of turtles taken in a region is challenging. High variability in bycatch rates within and among fleets constrains the estimation of total effects (Fig. 1). Because neither fishing effort nor turtles are randomly distributed in the ocean, variability in bycatch rates suggests that an average bycatch rate for a region may not represent the "real" bycatch rate. In addition, within a fleet the number of observed hooks typically ranges from 1-4% of the total number of hooks fished, so determining total bycatch means having to characterize what happened on the remaining 96–99% of hooks. There are some preliminary estimates of the number of turtles taken as bycatch in different longline fleets (Table 2). These estimates are important, but given the level of uncertainty, precision in these estimates beyond one or two significant digits is questionable.

The critical issue for an individual turtle is the likelihood of capture across an ocean region, not capture by a particular nation. With multiple fleets deployed the cumulative effects of pelagic longlines across fleets in large ocean regions must be taken into account. Because not all fleets have collected or released bycatch data, bycatch assessments for large ocean regions have to address missing data and deal with uncertainty and variability within a fleet. Not surprisingly, few researchers have tried to estimate bycatch across fleets and across an ocean region. Two recent studies that examine bycatch and subsequent mortality for leatherbacks in the Pacific Ocean illustrate the challenges in extrapolating across fleets. Using U.S. bycatch rates and basin-wide fishing effort for 1998, Kaplan (2005) estimated that across the Pacific at most 626 adult female leatherback turtles died from interactions with pelagic longline gear. Lewison et al. (2004) estimate mortality of both subadults and adults in longlines to be 1000–3200 in 2000. Relative to 1998, the 2000 estimates reflect the addition of >1 million hooks and the assumption that some international fleets had higher bycatch rates than U.S. vessels. Both estimates suggest that this bycatch is a cause for concern. Recent reports put the number of adult female leatherbacks nesting in the entire Pacific at 1500–3000 (Crowder 2000).

Given the known variability within and among fleets worldwide (Fig. 1), determining a precise point estimate for bycatch in any region may be unrealistic. Likewise, using smoothed bycatch averages or assuming a single bycatch rate within or among fleets may poorly estimate actual bycatch because neither turtles nor fishing vessels are evenly distributed in space and time, and not all fleets deploy their gear in the same way. Despite the limitations of such large-scale bycatch analyses, these studies are important because they provide provisional bycatch estimates, foster debate and discussion, facilitate more precise analyses, and ultimately improve our understanding of potential bycatch effects.

Other Fisheries

Of course, other fishing gears also incidentally take sea turtles. In fact, there is compelling, albeit sometimes preliminary, evidence that other fisheries may result in bycatch that is equal to or in many areas greater than pelagic

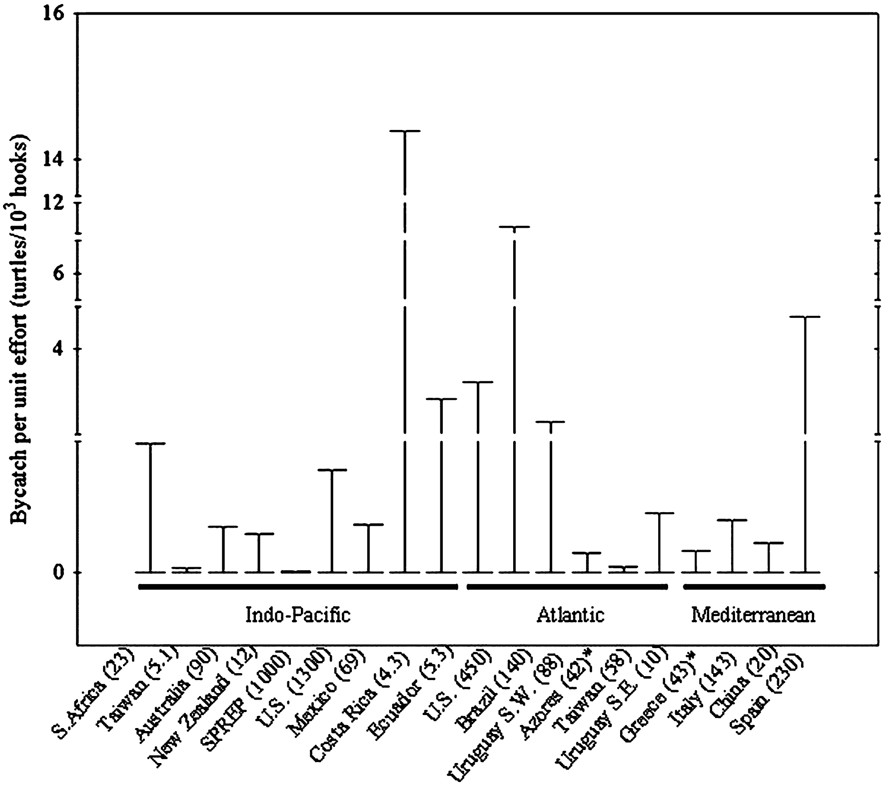

Figure 1. Reported bycatch rates (1995—present) from pelagic longlines targeting tuna, billfish, and sharks. The number in parentheses next to the fleet name shows the number of hooks observed (10^4) rounded to two significant figures. Reports made prior to 1995 or with <5000 observed hooks were excluded. For fleets marked with an asterisk (*), some of the reported effort for this fleet was either not included or not included as number of hooks. Data sources: AFFA 2001; Achaval et al. 2000; Arauz 2001; Bolten & Bjorndal 2005; Camiñas & Valeiras 2001; Carranza et al. 2006; Cheng 2000; CSLP 2001; Hernandez & Flores 2003; Hsia 2002; Largacha et al. 2005; Laurent et al. 2001; Lopez-Mendilaharsu 2003; Miller et al. 2005; NMFS 2005; Petersen 2005; Kotas et al. 2004; Marcovaldi 2005; Pinedo & Polacheck 2004; TAMAR 2004; SPREP 2001; Xiaojie & Liuxiong 2003. SPREP is the Pacific Regional Environment Programme.

longline bycatch. For example, as many as 3000 adult female leatherbacks may be caught each year by coastal gillnets deployed off Trinidad, with 35% mortality risk for entangled turtles (Lee Lum 2006). Studies of the gillnet fisheries in Brazil estimate a minimum bycatch of 200 leatherbacks/year (Marcovaldi et al. 2005). Reports from Baja, Mexico, show that similarly high numbers of turtles were caught in gillnets of only two fishing villages (H. Peckham, personal communication). The other important difference between potential effects of gillnet and longline gear on turtle populations is the probability of mortality once captured. Whereas longline mortality has been estimated to be as low as 4% (Aguilar et al. 1995; McCracken 2000; NMFS 2001; Camiñas 2004), gillnet mortality of sea turtles off France and Italy and in other areas has been reported to be 50% (Laurent 1991; Argano et al. 1992). Another gear type, trawl nets, from four Mediterranean countries catch approximately 10,000 turtles per year (in Camiñas 2004). The northern prawn fishery in Australia caught approximately 1000–4000 turtles, with an estimated mortality of 22% prior to turtle excluder device (TED) implementation (Robins et al. 2002). Since TED implementation, Australian trawl bycatch has been reduced dramatically (i.e., by at least 90%). But this pre-TED estimate is likely to be representative of the impacts of trawl fisheries that do not have adequate TED implementation or enforcement. Throughout the eastern United States, TED-equipped trawl fisheries are still permitted to take approximately 4000 turtles/year (TEWG 2000), and TED enforcement in the United States and other countries is still problematic (Lewison et al. 2003).

These reports suggest that bycatch and subsequent mortality from gillnets and bottom trawls is substantial. To understand the impact of bycatch in these gear types on sea turtle populations will require the same level of scrutiny that has been given to pelagic longline fisheries. Much more data are needed on the amount of bycatch incurred relative to the amount of trawl and gillnet gear deployed and on the size composition of caught turtles.

Other Threats

Fisheries bycatch is not the only factor that tends to take older age classes. Direct turtle harvests are still common in many areas, and these target older age classes (Seminoff et al. 2003; Koch et al. 2006). Efforts to stop direct harvest have been successful in some ocean regions and have resulted in dramatic population recoveries (Balazs & Chaloupka 2004). For declining populations

Table 2. Available fleet-based estimates of total turtle bycatch (not mortality) from pelagic longlines.[a]

Ocean region	*Total no. of turtles caught[b]*	*Source*
Pacific		
U.S.	500–800[c]	McCracken 2000
Japan	6,000	in NMFS 2004
Atlantic		
U.S.	1,000–2,000[c]	NMFS 2001
Mediterranean		
Spain	20,000–30,000	Caminas et al. 2001
Italy (Ionian Sea only)	100–1,000	Aguilar et al. 1995
Malta	1,500–2,500	Gramentz 1989
Greece	280	Panou et al. 1999
Morocco	3,000	Laurent 1990
Algeria	300	Laurent 1990
Cyprus	2,000	Godley et al. 1998

[a]*Most posthooking mortality estimates range from 4% to 27%. Table adapted from Tables 3–5 in Caminas (2004).*
[b]*In all cases, these are extrapolated estimates of total catch.*
[c]*Catch estimates predate spatial and temporal closures and implementation of mitigation measures.*

the cessation of direct exploitation will be critical. Other anthropogenic factors, such as egg predation, egg harvest, or beach development, affect nesting-beach activity and habitats. Clearly, a population that loses all or most of its hatchlings each year will eventually collapse. Conservation actions designed to protect sea turtle eggs, hatchlings, and nesting beaches are an important element of effective sea turtle conservation (Garcia et al. 2003; Fontaine & Shaver 2005; Marquez et al. 2005; Heppell et al. 2005*a*). But it is unclear how quickly these effects will cascade through a declining sea turtle population. This is of particular concern for particularly late-maturing sea turtles (i.e., loggerheads). Efforts focused solely on protecting eggs and hatchlings may not help a population's recovery if the number of nesting individuals continues to decline, a characteristic shared by the highest-risk populations (Crouse et al. 1987; Frazer 1992; Heppell et al. 1996; Heppell & Crowder 1998). For declining populations conservation efforts on nesting beaches may facilitate recovery, but unless reproductive individuals are also protected, these efforts are unlikely to prevent further declines.

Conclusions

Even if pelagic longline bycatch is not the largest single cause of fisheries-related mortality for sea turtles, there are several reasons why turtle bycatch by longlines should be, and is being, addressed. The first is its tendency to affect older, reproductively valuable, age classes of turtles. Data from several oceanic regions document that pelagic longlines affect demographically critical older age classes of turtles. Although bycatch rates from individual longline vessels are extremely low, the amount of gear deployed by longline vessels suggests that cumulative bycatch across fleets and ocean basins could be substantial. Current estimates suggest that even if pelagic longlines are not the largest single source of fisheries-related mortality, longline bycatch is certainly high enough to warrant management action in all fleets that encounter vulnerable turtles.

For industrial-scale longline fleets RFMO oversight provides an opportunity to implement and enforce mitigation measures that have been tested and shown to be effective across fleets and ocean regions. Significant progress has been made in reducing bycatch for some taxa, most notably seabirds (Gilman et al. 2005). More recently, circle hooks and mackerel bait have demonstrated promise in reducing bycatch of some sea turtles in the Northwest Atlantic longline fleet (Watson et al. 2005; Gilman et al. 2006). Several experimental fisheries are now underway to evaluate the ability of circle hooks to reduce turtle bycatch across species and fishing areas (Gilman et al. 2006). Reducing bycatch in artisanal longline fisheries will be more challenging, but grassroots outreach programs that work with fishers to introduce and test mitigation gear and methods have yielded promising results (Largacha et al. 2005).

Current data suggest that fisheries bycatch in general, and longline bycatch in particular, is one of many factors that are likely to negatively affect at-risk turtle populations. Short-term conservation plans for declining populations must also address bycatch from trawls, gillnets, and direct turtle harvests. Although the number and composition of sea turtles affected by gillnets and trawls are not known, existing data point to bycatch levels that are as high as or higher than longline fisheries. Effective mitigation measures have been developed for trawl fisheries, but implementation and enforcement of these measures has been problematic. Continued collection of bycatch data will not only provide an ability to assess current levels of bycatch but also provide a baseline to evaluate mitigation implementation and enforcement.

The challenge of conservation biology is to use the best available data to evaluate plausible hypotheses regarding the decline of species of concern. Because there are insufficient data to dismiss any of the putative threats to declining sea turtle populations, sea turtle conservation must address threats that turtles face in the water as well as on the nesting beaches. Without better data it is not possible to predict how declining populations would respond if all fisheries bycatch were eliminated; however, existing data suggest that unintended catch by fisheries (namely longlines, gillnets, and trawls) is an important source of mortality for sea turtle populations that must be managed. To achieve this, bycatch mitigation needs to be an integral element of management plans for sustainable fisheries. Developing analytical approaches that examine bycatch effects across a range of gear types will allow for a more meaningful evaluation of the cumulative effects of fisheries bycatch on vulnerable turtle populations. These integrated analyses, in conjunction with better demographic data, will bring us closer to evaluating the relative impact of these identified threats on sea turtle populations.

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