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REPORT

Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles

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Abstract

The depletion of fish stocks from global fisheries has been a long-standing concern. More recently, incidental catch of non-target (termed bycatch) vertebrates also has been proposed as a serious conservation issue. Here we present a bycatch assessment for loggerhead and leatherback sea turtles that are incidentally caught by global pelagic longlines. We integrate catch data from over 40 nations and bycatch data from 13 international observer programmes. Despite infrequent rates of encounter, our analyses show that more than 200 000 loggerheads and 50 000 leatherbacks were likely taken as pelagic longline bycatch in 2000. Our analyses suggest that thousands of these turtles die each year from longline gear in the Pacific Ocean alone. Given 80–95% declines for Pacific loggerhead and leatherback populations over the last 20 years, this bycatch level is not sustainable. Adopting a large-scale, synthetic approach is critical to accurately characterize the influence of global fisheries bycatch on globally distributed and imperilled pelagic vertebrates.

Keywords

Bycatch, global fisheries, leatherback, loggerhead, pelagic longlines, pelagic vertebrates, sea turtle.

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INTRODUCTION

Recent research has pointed to significant declines in targeted fish stocks from global industrial fisheries (Pauly *et al.* 1998; Myers & Worm 2003). Although not commercial targets, other pelagic species can also become entangled or hooked by the same fishing gear (Hall 1996); this incidental catch is termed 'bycatch' and is a management issue for all fishing fleets (Hall *et al.* 2000). Large marine vertebrates (e.g. sea turtles, seabirds, marine mammals, sharks) are among those most vulnerable to the negative effects of bycatch because of their late age at maturity and low reproductive rates (Heppell *et al.* 1999; Fujiwara & Caswell 2001; Baum *et al.* 2003; Lewison & Crowder 2003). Whereas fishing pressure on a target stock responds to target abundance, fishing pressure on bycatch species is likely to continue irrespective of bycatch abundance if the effects of bycatch are not assessed (Crowder & Murawski 1998).

Despite the existence of bycatch in all fishing fleets, there have been few attempts to quantify the magnitude and extent of protected species bycatch even for fisheries in which bycatch is perceived as a pressing concern. This is, in part, a consequence of limited data. Although international fishery commissions request voluntary reporting of the catch of target species over entire ocean basins, they have no regulatory authority over non-fish bycatch and few commissions have paid close attention to bycatch of threatened pelagic species. Unlike landing records for target species, bycatch monitoring must rely solely on onboard observers or on fishers' logbooks. Several nations employ observers to record bycatch of vulnerable species, but total observer effort is low. Another limitation of existing bycatch assessments has been a single nation or regional perspective, which constrains the applicability of such findings for globally distributed bycatch species. Whereas some research has addressed national bycatch issues and estimated regional fishing effort (Klaer & Polacheck 1997; Caswell *et al.* 1998; Gales *et al.* 1998; Tuck *et al.* 2001), these analyses have been limited in scale and data synthesis.

One fishery currently receiving considerable attention with respect to bycatch is the pelagic longline fishery. This gear's mainline stretches for tens of kilometres and dangles thousands of individually hooked lines; sea turtle bycatch is the result of turtles attempting to swallow bait or becoming entangled in gear. Pelagic longline bycatch has been implicated as a proximate cause for regional declines in two threatened sea turtle populations – loggerhead and leatherback sea turtles in the Pacific (Spotila *et al.* 2000). Despite these claims, the magnitude and extent of sea turtle bycatch from pelagic longlines has not been assessed, primarily because of the limitations of small-scale analyses to address this global issue. Here we present an integrated approach to fisheries bycatch assessment, synthesizing existing data at a spatial scale relevant to imperilled sea turtle populations and the global pelagic longline fishery.

PELAGIC LONGLINES AND SEA TURTLES

Pelagic longlines are used to catch tunas and swordfish around the world, with fishing effort extending across the Pacific, Atlantic and Indian oceans. Targeted species include bigeye (*Thunnus obesus*), albacore (*T. alalunga*), yellowfin (*T. albacares*) and bluefin tuna (*T. thynnus*), as well as swordfish (*Xiphus gladius*). Pelagic longlines catch 85% of the total landings of swordfish and more than 60% of bigeye and albacore tuna – totalling more than 680 000 metric tonnes (MT) of swordfish and tuna per year. Although many fishing nations contribute to the reported landings, a few fishing nations account for the majority of this catch, i.e. Japan and Taiwan account for more that half of this total (31 and 26% respectively) while no other single nation catches more than 7% of the total longline landings. In addition to reported landings, illegal, unregistered or unreported (IUU) vessels are believed to catch another 85 000 MT of tuna and swordfish [International Commission for the Conservation of Atlantic Tunas (ICCAT) 2001; SPC 2002; IOTC 2003; IATTC 2003].

Six of the seven extant sea turtle populations worldwide are listed in the IUCN Red List of Threatened Species (http://www.redlist.org/). In our analyses, we considered the two species caught most frequently by pelagic longlines – leatherbacks (*Dermochelys coricea*) and loggerheads (*Caretta caretta*). The most dramatic declines for these two species have occurred in the Pacific Ocean, where nesting populations of leatherback turtles have declined over 95% in the last 20 years (Crowder 2000; Spotila *et al.* 2000), and nesting populations of loggerheads have suffered an 80–86% decline over a similar time period (Kamezaki *et al.* 2003; Limpus & Limpus 2003).

METHODS

Fishing effort

To accurately characterize pelagic longline fishing effort, we compiled the most recent public domain data reported to fishery commissions in the Atlantic, Pacific and Indian oceans. We used three primary public domain data sources: ICCAT, Indian Ocean Tuna Commission, and the Secretariat for the Pacific Community Oceanic Fisheries Programme (ICCAT 2001; SPC 2002; IOTC 2003). All data were entered and mapped in ArcGIS 8.1 (ESRI, Inc. Redlands, CA, USA). All ocean regions were divided into 5 × 5° grid cells. Locations, described by latitude and longitude, were binned into grid cells by aggregating finer (1 × 1°) or parsing larger (10 × 10° or 20 × 20°) cells evenly. Where fleet nationality was provided (Atlantic and Indian Ocean records), fleet information was retained. Data included in this analysis reflect fishing effort for 2000, the most recent year for which data have been released from all commissions. Although some regions contain no pelagic fishing effort (e.g. the Southern Ocean, Gulf of Alaska and Pacific coast of South America), they may contain demersal (bottom-set) longline effort. As demersal longlines have not been implicated as a source of sea turtle bycatch, we did not include this gear type in our analysis.

Data from the Pacific and Indian oceans included information on catch (measured in MT) and effort (numbers of hooks set) per fishing location (latitude and longitude) per quarter. We binned this information according to 5 × 5° grid cell and calculated catch per unit effort (CPUE) per grid cell (i.e. catch of target species in MT per 1000 hooks). However, Atlantic (including Mediterranean) data were released in several forms. The majority of nations fishing in the Atlantic (70% of data) report catch, effort and fishing location; these data were binned and CPUEs were calculated as described above. Approximately 2% of the Atlantic data came from nations that reported catch and fishing location, but no information regarding effort. We converted these catches to effort using weighted CPUEs from reported effort data in the same 5 × 5° grid cell. CPUEs were weighted by number of hooks to account for differences in hooks per estimate. If no CPUE was reported for a particular grid cell, we used the weighted average CPUE from all contiguous grid cells. The remaining 28% of Atlantic data included all other countries that were known to have caught ≥100 MT of tuna or swordfish, but reported neither catch nor effort to ICCAT. For these data, we based fishing location on a public domain 1997 ICCAT spatial database (CATDIS; ICCAT 2001) and rescaled each nation's 1997 catch per grid cell to reflect 2000 catch levels. This catch was then converted to effort using the weighted average CPUE method described above.

Previous research has revealed that longline sets that target swordfish have turtle bycatch rates *c.* 10 times higher than bycatch rates in tuna sets (Crowder & Myers 2001). To maintain this distinction, fishing effort was categorized into two target categories (tuna or swordfish). If target was not reported, we defined the target as the fish species with the largest catch. All effort data were stratified by target (swordfish or tuna), by season (quarterly) and by location ($5 \times 5°$ grid cell).

Sea turtle bycatch

We compiled all available bycatch rate information (Fig 1, see Supplementary Information for data sources). This included raw observer data, observer data summaries and bycatch assessments from other methods (e.g. questionnaires) from 13 countries. Bycatch data were stratified by species (loggerhead or leatherback), by target (swordfish or tuna), by season (quarterly) and by location ($5 \times 5°$ grid cell).

To calculate an initial estimate of the number of turtles caught in 2000, we accounted for target-specific fishing effort that overlapped a recorded bycatch rate directly in space ($5 \times 5°$ grid square) and time (yearly quarter). We refer to this as our minimum documented bycatch estimate. As the minimum documented estimate, by definition, does not account for all pelagic fishing effort in 2000, we used this estimate to extrapolate bycatch from all reported pelagic longline effort by scaling the estimates by the percentage of remaining hooks. We also estimated bycatch from all reported pelagic longline effort using basin-specific average bycatch rates for each turtle species, with fishing effort and bycatch data stratified by target. These basin averages were the mean of per country means by target within a basin, multiplied by the total effort within that basin. Although no bycatch rates have been released for the Indian Ocean, this ocean supports a relatively high level of pelagic longline effort (>140 million hooks per year). To include this region in our global turtle bycatch estimate, we therefore applied the median of the Atlantic and Pacific bycatch rate averages to Indian Ocean effort. We compared results between the two extrapolation methods (minimum estimate and basin averages) as an indication of estimate stability.

To minimize the effect of any one bycatch event, we divided all observed bycatch by all observed effort in each grid cell with multiple data records. We accounted for temporal and spatial variability in bycatch rates (and thus in bycatch estimates) by calculating the standard deviation of bycatch per unit effort from the US observer data in the Atlantic and Pacific. We used the US National Marine Fisheries Service (NMFS) data to characterize variability because it was the only raw data set available to us. We calculated the standard deviation for all $5 \times 5°$ grid cells for all quarters that had more than one bycatch data record in the Atlantic and Pacific. From this distribution of standard deviations, we used a bootstrapping procedure (1000 replications of sampling with replacement) to identify the mean standard deviation for each basin. We used the mean standard deviations to calculate a one-tailed 95% confidence interval for the basin-average extrapolation method. We truncated the interval to reflect positive bycatch rates and thus to yield positive bycatch estimates. Throughout the analysis, we selected the lower values of estimated intervals in calculating and reporting bycatch and bycatch effects.

Probability of a bycatch event and mortality

To put our derived bycatch estimates into a population context, we relied on published demographic information for loggerheads and leatherbacks, and focused our attention on populations in the Pacific where the most dramatic population declines have been reported. The reported declines in the Pacific are based on extensive beach survey efforts that have recorded the total number of nests and nesting turtles over the past 15–20 years for both species (Spotila *et al.* 2000; Kamezaki *et al.* 2003; Limpus & Limpus 2003).

Using our bycatch estimates for the Pacific, we calculated the probability of an individual Pacific loggerhead or leatherback being caught as bycatch. To do this, we defined the annual bycatch probability, P_{bycatch}, for each turtle species as the probability that a turtle would get caught in pelagic longline gear as

$$P_{\mathrm{bycatch}} = T_{\mathrm{bycatch}}/T_{\mathrm{v}} \qquad (1)$$

where P_{bycatch} was calculated as T_{bycatch}, the number of turtles caught as bycatch (see 'Sea turtle bycatch') divided by T_{v}, the number of turtles vulnerable to being caught by pelagic longline gear in each population. We calculated the number of Pacific loggerheads and leatherbacks vulnerable to longline gear, T_{v}, as:

$$T_{\mathrm{v}} = V \times T \qquad (2)$$

$$T = [(N_{\mathrm{f}}/P_{\mathrm{Nf}}) \times 2] \qquad (3)$$

where V is the proportion of turtles vulnerable to longline gear based on body size distribution of observed bycatch and T is the total population size. N_{f} is the total number of nesting-aged females, and P_{Nf} is the total proportion of nesting-aged females relative to the total population. V was calculated as 20% based on the size distribution of turtles recorded by the US NMFS observer programme, and the estimated age distributions (Heppell *et al.* 2004; M. Snover personal communication). N_{f} was based on nesting females observed annually from all major rookeries multiplied by 2 to represent the fact that a given female nests on average every 2 years. Recent estimates put the number of nesting females at *c.* 1500 for both loggerheads and leatherbacks (Spotila *et al.* 2000; Kamezaki *et al.* 2003; Limpus & Limpus 2003). For loggerheads, P_{Nf} is 1.8%, based on the stable age distribution for Atlantic loggerheads (M. Snover personal communication). Age distribution data is not available for

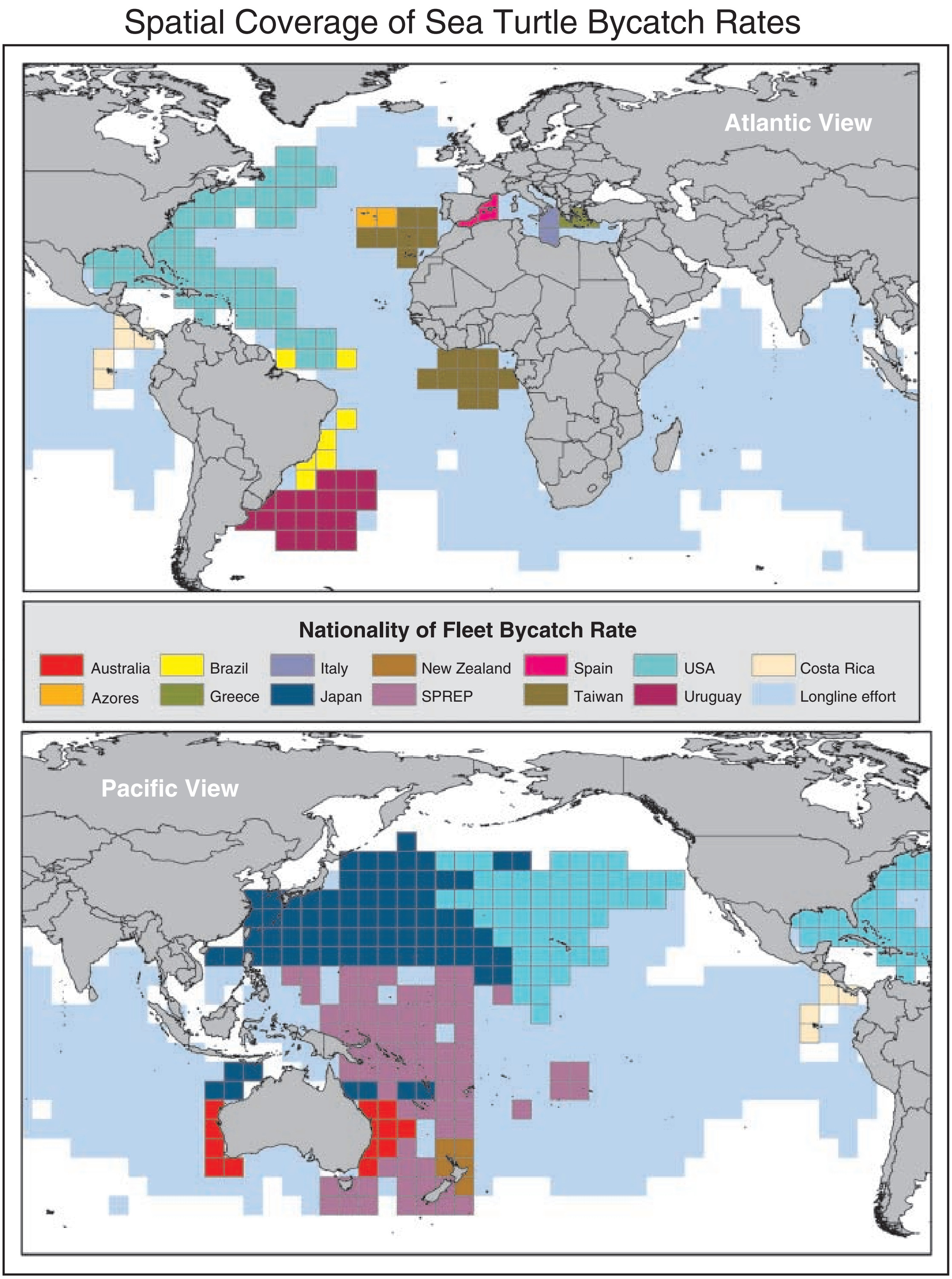

Figure 1 Map of all available bycatch rates includes in the estimate. Bycatch rates were derived from observer data, observer data summaries and assessments for other methods, including questionnaires. *SPREP, South Pacific Regional Environment Programme, including Cook Islands, Fiji, Guam, Kiribati, Mariana Islands, Marshall Islands, Micronesia, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, and Vanuatu.

leatherbacks; we assumed that P_{Nf} for leatherbacks was 3.75%, the value for Kemp's ridley (*Lepidochelys kempii*) turtles, a species with a comparable age of first reproduction (Heppell *et al.* 2004). We multiplied the total number of females by 2, assuming a 50–50 sex ratio, to calculate the total population (T).

As pelagic longlines have been documented to cause selective mortality among older age classes, deviations from a stable age distribution are plausible. To consider the affect of deviating from a stable age distribution on the calculated annual bycatch probability, we considered a range of values for the two parameters derived from the stable age distribution – P_{Nf}, the proportion of nesting-aged females in the population and V, the proportion of turtles vulnerable to longline gear. As these two parameters are linked (nesting-aged females are a subset of vulnerable turtles), we varied the parameters to account for the relative proportional change between them.

Although not every turtle interaction with longline gear is lethal, the probability of mortality per take remains uncertain. To estimate the approximate level of mortality from longline bycatch, we calculated the proportion of hooked turtles that die from gear interactions. This number is the product of the bycatch probability and the post-hooking mortality estimates. These mortality estimates reflect immediate and delayed mortality as a result of interaction with longline gear, and were estimated by the US NMFS as 17–42% for loggerheads, and 8–27% for leatherbacks (NMFS 2001a). These estimates are based on the largest bycatch data set available that accounts for immediate and delayed mortality. To calculate the number of turtles that were likely to be killed by pelagic longlines in the Pacific in 2000, we multiplied our lowest estimate of the number of loggerheads and leatherbacks caught annually in the Pacific by the probability of capture and the species-specific mortality rates.

RESULTS

Fishing effort

We estimate that pelagic longline fleets from 40 nations set *c.* 1.4 billion hooks in the water in one year (2000), which is equivalent to *c.* 3.8 million hooks every day (Fig. 2). Over half (52%) of the total fishing effort occurred in the Pacific Ocean (the largest by area), while the remaining effort was in the Atlantic (37%) and the Indian Ocean (11%). Six times more fishing effort targeted tunas (1.2 billion hooks) than swordfish (200 million hooks).

Four primary hotspots of pelagic longline effort emerge: the area south of Kiribati in the central Pacific Ocean, the region between Indonesia and the Philippines, the Mediterranean Sea and the central southern Atlantic Ocean. Although the data from the Pacific Ocean are not nation specific, global landings suggest that Japan and Taiwan are primary fleets in this region. Indonesian fleets also report significant longline landings (45 000 MT per year), likely from artisanal fisheries in the same area. Intense longline effort in the Mediterranean primarily comes from European and African fishing nations (i.e. Spain, Italy, Greece, Libya), while the south Atlantic hotspot reflects heavy fishing by China, Equatorial Guinea and several Central American fleets (i.e. Belize, Honduras, Panama).

Sea turtle bycatch

Turtle bycatch rates from swordfish and tuna vessels ranged from 0 to 14 loggerheads, and 0 to 2.4 leatherbacks per 1000 hooks. There were no clear trends in bycatch rates by latitude, although there were significant differences between ocean basins. Atlantic and Mediterranean bycatch rates were higher than Pacific rates across tuna and swordfish fleets for both turtle species (Kolmogorov–Smirnov, $P < 0.01$). These differences may be the result of higher rates of encounter in the Atlantic, which may reflect different fishing practices regarding the use of oceanographic or bathymetric features, or different population sizes or trends between ocean regions.

Our minimum documented estimate of bycatch accounted for 26% (349 million hooks) of the total annual hooks for loggerheads, 22% for leatherbacks (288 million hooks), and yielded a minimum bycatch estimate of *c.* 60 000 loggerheads and 9000 leatherbacks. Extrapolating to account for the remaining hooks, this yielded an estimate of 220 000 loggerheads and 50 000 leatherbacks caught globally as bycatch in 2000. A second extrapolation method based on the basin-wide average bycatch rates yielded similar estimates of *c.* 250 000 loggerheads and 60 000 leatherbacks caught globally as bycatch in 2000. The concurrence of the estimates from the two extrapolation methods suggests estimate stability.

Bycatch per each ocean basin was calculated using the basin-average extrapolation method (Fig. 3). The estimate intervals are in large part determined by the amount of observer coverage in each basin; basins with low observer coverage have larger standard deviations. For example, we estimated 60 000–80 000 loggerheads are caught in the Mediterranean, based on bycatch data that were applicable to 80% of reported fishing effort. In contrast, the estimate for leatherbacks in the Mediterranean covers two orders of magnitude. However, even accounting for the varying extent of observer coverage, there are still differences between basins. Although observer coverage is greater for the Pacific than the Atlantic, there appears to be higher variability in the Pacific, either because of fewer turtle encounters, different fishing practices or a combination of factors.

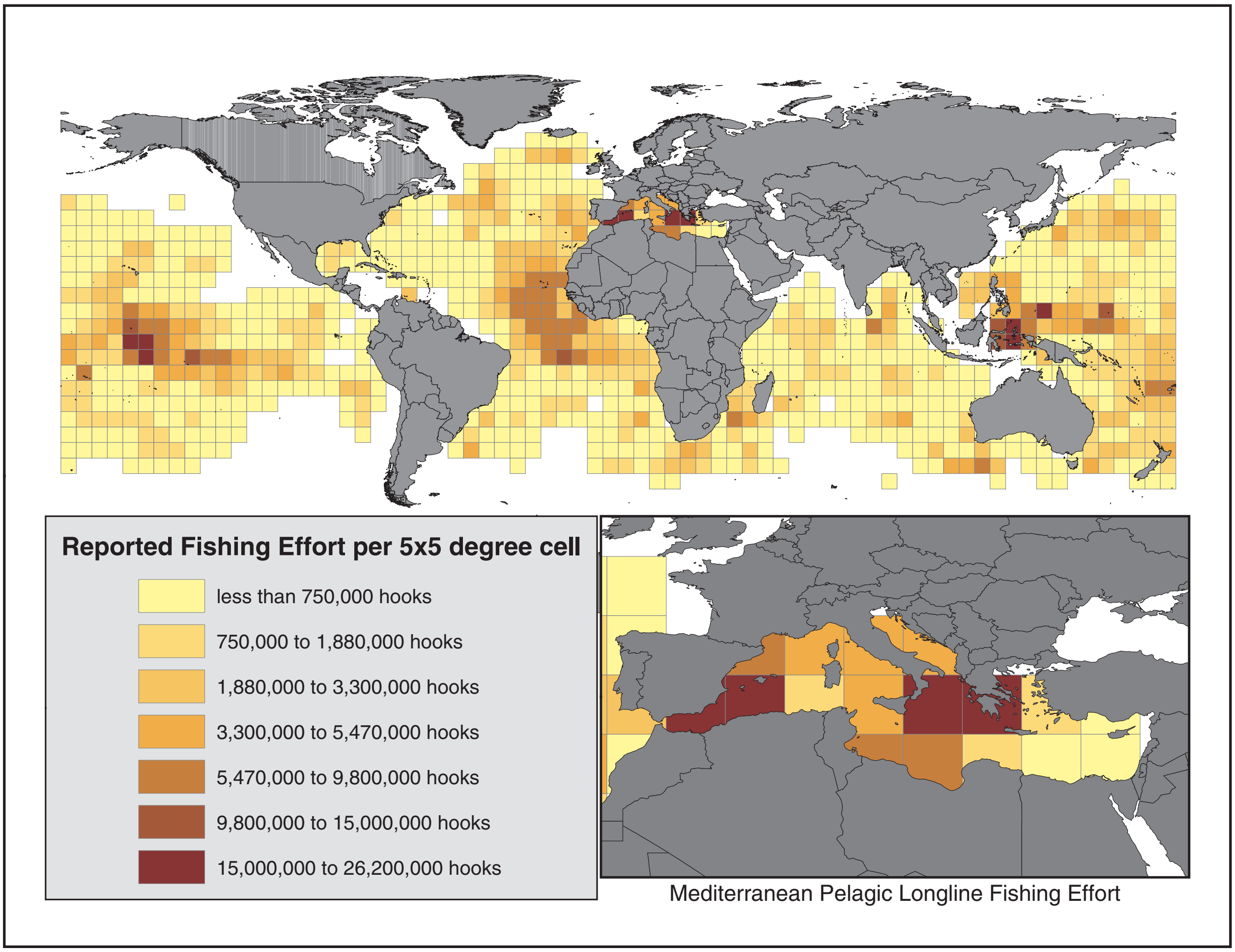

Figure 2 Map of reported pelagic longline effort, including all tuna and swordfish directed effort for 2000. Hotspots of high fishing effort are shown in brown.

Probability of a bycatch event and mortality

Based on eqn 3, total population sizes in the Pacific were calculated to be *c.* 335 000 loggerheads and 160 000 leatherbacks. Of these, an estimated 67 000 loggerheads and 32 000 leatherbacks are in size classes vulnerable to pelagic longline bycatch. From the Pacific fishing effort and bycatch rate data, we estimated that 30 000 loggerheads and 20 000 leatherbacks were caught in 2000 as bycatch by pelagic longlines throughout the Pacific. This yielded annual bycatch probabilities of 0.45 and 0.63 for Pacific loggerheads and leatherbacks respectively, and suggests that vulnerable loggerheads and leatherbacks in this region are taken as bycatch on average once every 2 years. Combining these bycatch probabilities and NMFS mortality estimates, we estimate that between 2600 and 6000 loggerheads and between 1000 and 3200 leatherback turtles were killed by pelagic longline gear in 2000 in the Pacific alone.

Although the annual bycatch probabilities were derived using parameters associated with a stable age distribution, the calculated probabilities were robust to deviations from that distribution (Fig. 4a and b). Even assuming the lowest (and unlikely) percentage of nesting-aged females in each population, 0.6 and 2.25% for loggerheads and leatherbacks, respectively, the resulting annual bycatch probabilities in the Pacific are still high enough to warrant management action under protected species legislation.

DISCUSSION

Fisheries management faces the growing problem of reducing the bycatch of protected pelagic species, namely sea turtles, sea birds, marine mammals and sharks. Despite the concerns of the public about declining populations of these species, bycatch assessments have been limited in temporal and spatial scale, and, thus, in applicability to this

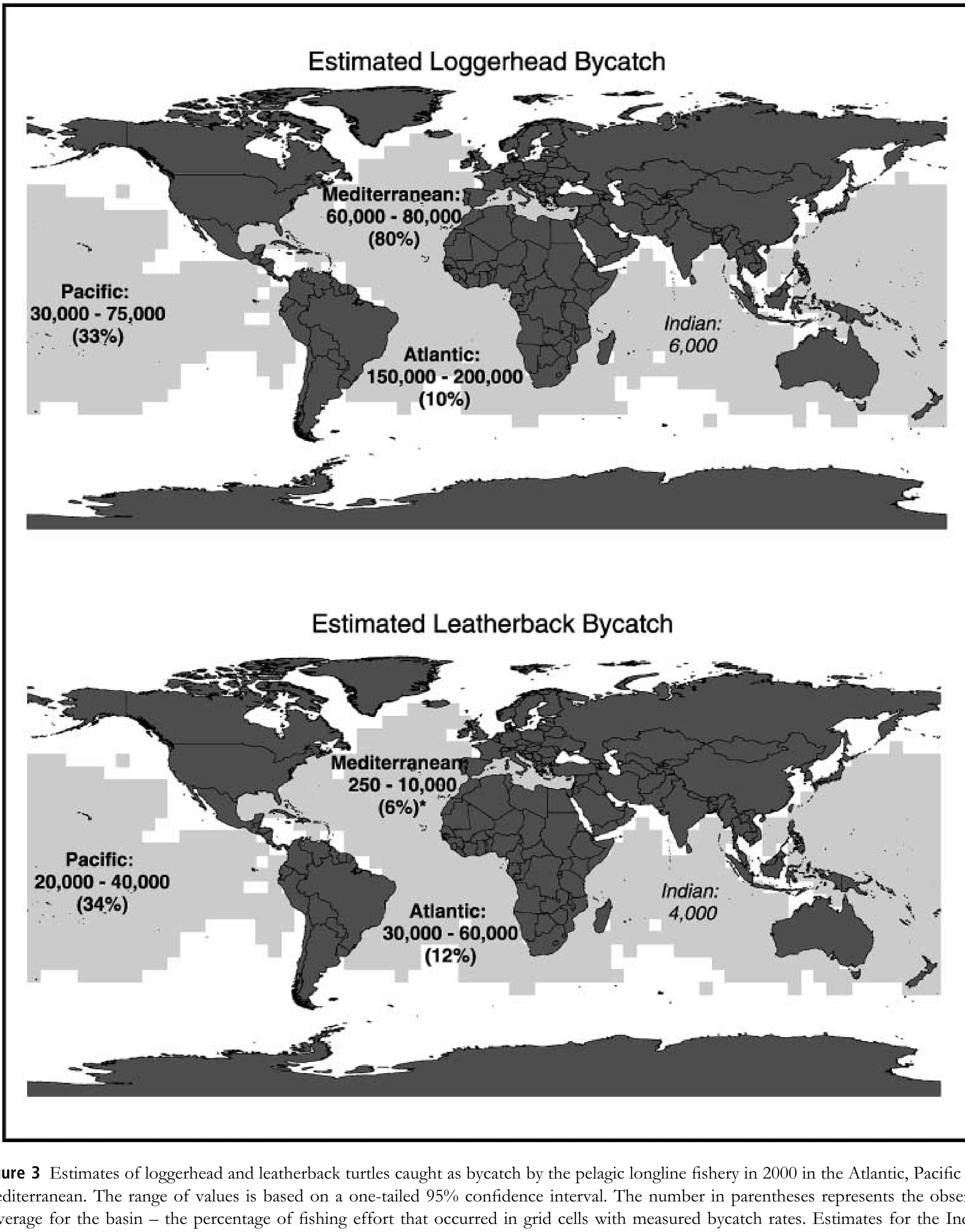

Figure 3 Estimates of loggerhead and leatherback turtles caught as bycatch by the pelagic longline fishery in 2000 in the Atlantic, Pacific and Mediterranean. The range of values is based on a one-tailed 95% confidence interval. The number in parentheses represents the observer coverage for the basin – the percentage of fishing effort that occurred in grid cells with measured bycatch rates. Estimates for the Indian Ocean are shown in italics to indicate that no bycatch data has been published or released for this region. Indian Ocean estimates are based on median bycatch rates from the Atlantic and Pacific. *Lack of recorded zeros for leatherbacks may contribute to the low level of observer coverage for this species in the Mediterranean.

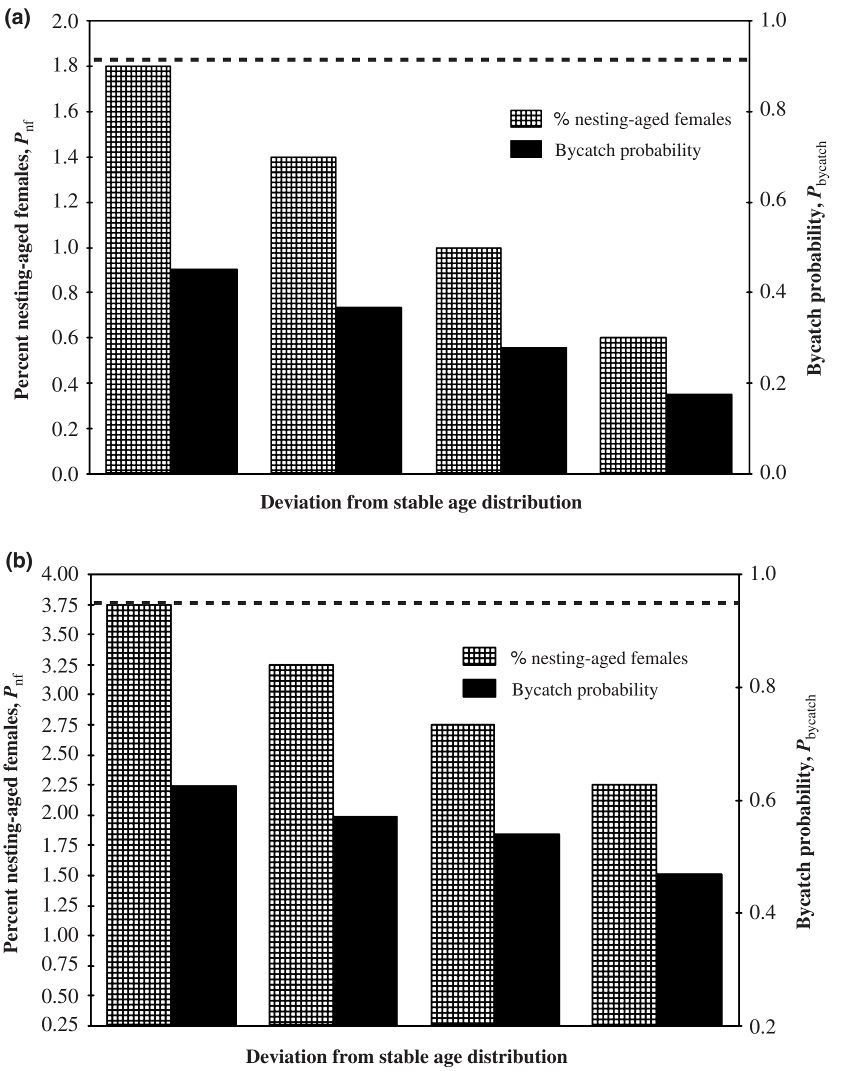

Figure 4 The influence of deviating from the stable age distribution P_{nf}, where P_{nf} is the percent of nesting-aged females in the total population, on the estimates of the annual bycatch probability ($P_{bycatch}$) for (a) loggerheads and (b) leatherbacks. Annual bycatch probability is calculated as the ratio of the number of turtles caught ($T_{bycatch}$) to the number of turtles vulnerable to being caught (T_v). Dashed line represents stable age distribution value for P_{nf}.

global conservation problem. Here we present an assessment framework that integrates data at relevant spatial scales for two protected and globally distributed pelagic sea turtle species. Although sea turtles are the focus of this paper, the large-scale, synthetic approach presented here is applicable to other globally distributed taxa (e.g. seabirds, marine mammals and sharks) caught by pelagic longlines and other global fisheries. Beyond the basic question of what impact a fishery has on species taken as bycatch, large-scale bycatch assessments may also point to important regional differences in how bycatch species and fishing vessels interact. The significant differences in bycatch rates between the Atlantic, Mediterranean and Pacific may result from different fishing gear, fishing practices or simply reflect divergent trends in abundance of bycatch species among regions. These differences have yet to be explicitly considered.

Worldwide pelagic longline fisheries were likely to have caught at least 200 000 loggerheads and 50 000 leatherbacks turtles in 2000. Based on the estimates of mortality from NMFS, tens of thousands of turtles die from these encounters around the world. In the Pacific, where regional nest surveys record the majority of nesting activity, precipitous declines in nesting females on all major Pacific rookeries (Fig. 5) suggest that unmitigated longline bycatch will have serious consequences for both loggerheads and leatherbacks in the Pacific. Population projections calculated from Costa Rican leatherback nesting data in 1995, when nesting counts were higher than today, suggested adult leatherback mortality from fisheries greater than 1% would lead to population collapse (Spotila *et al.* 1996). Our analyses suggest this mortality threshold is likely being exceeded for both loggerheads and leatherbacks in the Pacific. Other sources of mortality may also be contributing to regional loggerhead or leatherback

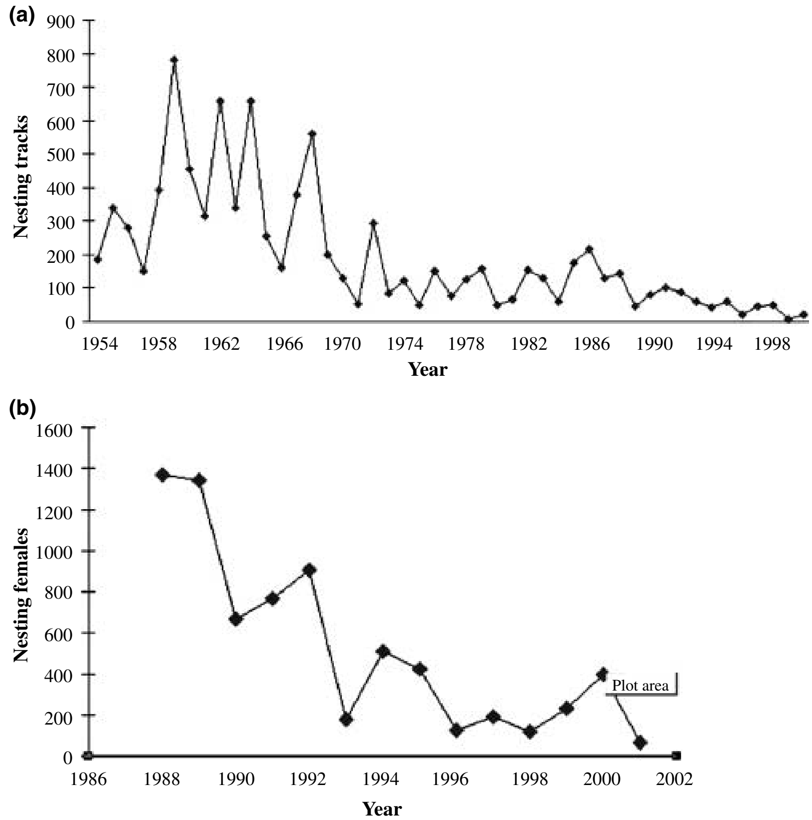

Figure 5 Trends of nesting activity from major nesting beaches in the Pacific for (a) loggerheads in Kamouda Beach, Japan (Kamezaki *et al.* 2003) and (b) leatherbacks in Playa Grande, Costa Rica (Spotila *et al.* 2000). Similar trends have been reported for other nesting beaches (Limpus & Limpus 2003, L. Sarti and S. Eckert personal communication).

declines: egg mortality from human and other predators, loss of beach habitat, and bycatch from other fisheries, such as gillnets and trawls (NMFS 2001b; Lewison *et al.* 2003). Like pelagic longlines, gillnets and trawl nets catch large subadults and adults, age classes that are sensitive to perturbation and can strongly affect population growth rates (Crowder *et al.* 1994; NMFS 2001b; Bolten 2003). These additional mortality sources must also be assessed and mitigated.

Just as bycatch assessments must be made at relevant spatial scales, so too must management actions that are designed to reduce or eliminate turtle bycatch. The United States has implemented both temporary and permanent fishery closures to reduce turtle bycatch and protect turtle populations (NMFS 2000a,b). However, the basin-wide distributions of both pelagic longline effort and sea turtles, coupled with the relatively small US contribution to total pelagic longline effort (*c.* 2% of worldwide landings), suggest that effective protection for loggerheads and leatherbacks will require coordinated international action (Crowder 2000). Experimental fisheries have identified some gear modifications and fishing practices that reduce sea turtle bycatch (e.g. circle hooks, mackerel bait, leaded swivels; Watson *et al.* 2003), but multinational efforts are needed immediately to continue to develop and implement mitigation measures that can reduce or eliminate turtle bycatch across fleets and basins.

Of necessity, our analysis relies on fishing statistics voluntarily reported by member states in the international fishing commissions, and on published or released bycatch rates from individual nations. Thus, our calculations are subject to error from data limitations. Although the quality of the data available may limit the precision of our estimates, we believe our calculations of longline effort and turtle bycatch are reasonable assessments of the magnitude of actual effects. Our estimates were robust to deviations in demographic assumptions and were all based on the lowest values from estimate intervals. The precautionary principle as applied to endangered species management suggests that we should seek to reduce mortality for sea turtles, particularly in the Pacific, both on land and at sea.

The large bycatch estimate ranges found in ocean areas where observer coverage is low demonstrate that widespread observer coverage is critical to precisely characterize the extent and magnitude of fisheries bycatch. Despite data limitations and uncertainties, the non-trivial risk of extinction for some populations of sea turtles warrants the use of the best available data to provide bracketed estimates of the magnitude of current bycatch problems and, if demographic information is available, to place bycatch into a population context. As long as bycatch assessments use transparent and defensible methodologies that can be replicated and revised once higher quality or more data become available, these assessments can provide a meaningful management tool. Although more data collection may always be warranted, there is currently sufficient data available to inform resource managers on the need for intervention, particularly in the Pacific. An integrated approach that replaces the single nation or regional perspective with a global one, and synthesizes data from fishery commissions and data on protected species can provide critical insights to those interested in managing oceanic pelagic organisms at the appropriate scale. Actions of individual nations may do little to prevent wide-ranging pelagic organisms such as sea turtles from sliding to extinction. Conserving sea turtles, and other global bycatch species, will require ocean-scale assessments in conjunction with international action.

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