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An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries

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ABSTRACT

Recent case studies have highlighted high bycatch mortality of sea turtles and marine mammals in artisanal fisheries, but in most countries there are few data on artisanal fishing effort, catch, or bycatch. With artisanal fisheries comprising >95% of the world's fishermen, this knowledge gap presents a major challenge to threatened species conservation and sustainable fisheries initiatives. We report on results from an intensive pilot study to evaluate whether interview surveys can be effective in assessing fishing effort and threatened species bycatch. Fisheries and bycatch data from interviews with >6100 fishermen in seven developing countries were collected in <1 year for approximately USD $47,000, indicating that this approach may rapidly yield coarse-level information over large areas at low cost. This effort provided the first fisheries characterizations for many areas and revealed the widespread nature of high bycatch in artisanal fisheries. Challenges to study design and implementation prevented quantitative estimation or spatial comparisons of bycatch during this pilot research phase, but results suggested that annual sea turtle bycatch may number at least in the low thousands of individuals per country. Annual odontocete bycatch may number at least in the low hundreds per country. Sirenian bycatch occurred in all study areas but was frequent only in West Africa. We discuss lessons learned from this survey effort and present a revised protocol for future interview-based bycatch assessments.

1. Introduction

The intentional or accidental catch of marine mammals and sea turtles in fisheries can pose significant threats to populations (Lewison et al., 2004; Kappel, 2005). Populations of these taxa are especially vulnerable to mortality from anthropogenic sources because of their slow maturity and reproduction rates (Musick, 1999; Heppell et al., 2000). For many years, attention to the bycatch issue has focused almost exclusively on industrial fisheries (Soykan et al., 2008). However, recent evidence has highlighted the potential for artisanal fisheries in developing countries to have significant negative impacts on these taxa (e.g., Lee Lum, 2006; Peckham et al., 2007, 2008; Jaramillo-Legorreta et al., 2007; Mangel et al., 2010). These case studies suggest that greater attention to impacts of artisanal fisheries on large marine vertebrates is needed. Artisanal fisheries are globally ubiquitous and may account for >95% of the world's fishers (Pauly, 2006), so the scope of this issue may be enormous.

Two types of information are needed to quantify and spatially characterize fisheries bycatch: a measure of fishing effort and a bycatch rate (e.g., number individuals taken per unit of fishing effort). It is generally accepted that the most accurate method to quantify bycatch rates involves using independent observers on board fishing vessels to record information on per-vessel fishing effort

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(e.g., fishing trip duration, number of gear-sets per trip), target catch, and bycatch (Alverson et al., 1994; Kennelly, 1999; NMFS, 2004). Given complementary information about the size of the fishing fleet (e.g., number of vessels) and per-vessel effort (e.g., number of trips or gear deployments), bycatch per unit effort can be extrapolated to the entire fishery to estimate total bycatch (Rago et al., 2005).

Unfortunately, whereas these types of data are available for many industrial fleets, artisanal fisheries typically are data poor (Kelleher, 2005; Salas et al., 2007; Chuenpagdee and Pauly, 2008; McCluskey and Lewison, 2008). Many artisanal fishing boats in developing countries are not registered, and the number of registered boats may not represent the number of active fishers (Chuenpagdee et al., 2006), so national and global fisheries statistics may not provide an accurate picture of fishing capacity or activity. The costs of implementing observer programs in developing countries are often prohibitive, especially given that artisanal fisheries consist of large numbers of boats distributed diffusely (as opposed to in centralized ports) along the coasts. In contrast to specialized industrial fleets that consistently target the same species and have finite fishing seasons, artisanal fisheries are generally flexible, dynamic and operate much of the year (Salas et al., 2007). Therefore, season-specific estimates of per-vessel effort or bycatch may not be applicable to other vessels or to other times of the year. Small boat sizes typical of artisanal fisheries also make on-board observing logistically difficult; there simply may not be enough room to accommodate observers. Vessel logbooks may be employed as a low-cost alternative to observer programs in industrial fisheries and in some countries may provide useful fishing effort information. However, catch and bycatch data are from logbooks are often incomplete or suspect (Kennelly, 1999; NMFS, 2004; Walsh et al., 2005). In fisheries that consist of thousands of vessels with little or no management infrastructure logbooks are not kept.

In the absence of empirical datasets, researchers have increasingly relied on the knowledge of local fisherman to better understand artisanal fisheries and their interactions with coastal ecosystems (Johannes et al., 2000; Drew, 2005; Close and Hall, 2006). Despite the limitations of social survey data (Kennelly, 1999; Huntington, 2000; Gilchrist et al., 2005), interviews have provided useful information about marine mammal and sea turtle bycatch in both artisanal and commercial fisheries when observer data were limited or not feasible to collect (Silva and Best, 1996; Van Waerebeek et al., 1997; Godley et al., 1998; D'Agrosa et al., 2000; Amir et al., 2002; López et al., 2003; Carreras et al., 2004; Lee Lum, 2006; Karamanlidis et al., 2008). But most interview-based bycatch studies have been somewhat restricted in spatial scale or have focused on particular fisheries not necessarily representative of those in the broader geographic area. These limit the generality of inference drawn from bycatch estimates or other described characteristics of the fisheries. Moreover, typically sparse descriptions of interview methodology (White et al., 2005) and lack of standardized interview protocols (Neis et al., 1999; Davis and Wagner, 2003) mean that data reliability is difficult is to assess and that results across studies may not necessarily be comparable, since numerical estimates based on indirect approaches such as interviews have been shown to vary with the methodology used (Lien et al., 1994; Gomm, 2004; Fowler, 2009).

Researchers, managers, and conservation organizations have limited resources and therefore need to make strategic decisions about how to most effectively focus their work and funding. Substantial information gaps about the magnitude and distribution of large vertebrate bycatch in artisanal fisheries prevent timely informed decision-making. Recognizing that it is not feasible to comprehensively fill these global knowledge gaps through dozens or hundreds of intensive field studies, we explored whether rapidly implemented, low-cost, standardized interview surveys could be effective for assessing fishing effort and bycatch. If so, these could be used as a first step in a prioritization process. A growing body of research has favored using local knowledge over more expensive and time-consuming methods to characterize rapidly occurring environmental threats and establish conservation priorities (Balram et al., 2004; Gavin and Anderson, 2005; Jones et al., 2008; Anadón et al., 2009).

In this paper, we describe results and lessons learned from a large pilot study of a rapid bycatch assessment protocol. The study uses interview surveys with fishermen, implemented using consistent methodologies across multiple countries within one or more large geographic regions to collect comparable information on artisanal fisheries effort, gear use, and bycatch of vulnerable taxa. For the purpose of this paper, we refer to 'bycatch' of marine mammals and sea turtles as all captures occurring outside of direct-harvest fisheries for these taxa; this is consistent with a recently proposed definition of the term by Davies et al. (2009).

We developed and implemented an interview survey protocol in seven developing countries. Multiple locations were chosen to evaluate the protocol across a range of cultures infrastructure, fisheries types, bycatch characteristics, in-country research teams, and to evaluate the scope and scale of challenges to this approach. Our objectives were to: (1) characterize gear use and fishing effort of artisanal fisheries and obtain semi-quantitative estimates of bycatch of marine mammals and sea turtles that are comparable across regions; (2) determine if the protocol could be implemented cost-effectively, over a relatively short time frame; and (3) document lessons learned to improve the usefulness of surveying fishermen to collect bycatch and fishing effort data in artisanal fisheries.

2. Methods

2.1. Surveys

In-person surveys were conducted during 2007 and 2008 in fishing communities from seven countries: Sierra Leone, Cameroon, Nigeria, Tanzania, Comoros, Malaysia, and Jamaica. We chose these countries to provide a spatially heterogeneous global sample (two in West Africa, three in East Africa, one in Asia, one in Caribbean) and where existing collaborations increased our confidence in successfully implementing surveys in a low-cost, rapid manner.

Our surveys consisted of three components: long questionnaire, short questionnaire and a port description form (Appendix 1). The long and short questionnaires included mostly closed questions and were completed in-person with fishermen at landing sites; they included questions about fishers' practices, gear use, and bycatch of marine mammals and sea turtles. Relatively short (<30 min) closed-question surveys have generally been recommended for collecting quantifiable or factual information (Huntington, 2000; Fowler, 2009; Gomm, 2004; White et al., 2005). The short questionnaire was a subset of the long questionnaire and was intended for fishermen with only 5–10 min to spare for an interview, so as to maximize the amount of bycatch information collected. It contained questions on type of gear used, how many marine mammals and sea turtles were caught per month or year, and what the fishermen did with captured animals. The long questionnaire also included more detailed questions about fishing gear usage, target species catch, boat specifications, and seasonality and location of fishing effort. It was designed to be used with fishing community leaders and to be completed in approximately 20–30 min. The port description forms did not involve interviews; field workers used them to record boat-count estimates and a general characterization of each visited fishing port or village (e.g., gear types used, boat descriptions, general physical description of the landing site).

2.2. Interviewer training and survey implementation

Each country had an in-country coordinator (hereafter 'coordinator') who modified the interviews, developed training sessions, supervised interviewers, and collated data. Coordinators were citizens or permanent residents of the study countries and were experienced working in fishing communities there, but they varied with respect to profession (e.g., academic researcher, fisheries officer, NGO worker) and specific expertise (e.g., sea turtle biology, marine mammal biology, fisheries, community development). Coordinators were given the standard interview forms and were allowed to revise them as appropriate for implementation in their countries. They were asked to add questions as necessary, but not to delete questions, to ensure a core set of information was gathered consistently across countries.

Coordinators in each country developed 1- to 9-day long training sessions for their team of interviewers, which varied in size from five to eight members. The backgrounds of interviewers varied from university students and interns to fisheries institute research staff (with master's or doctoral degrees), technicians (bachelor's level), and community members experienced at conducting surveys. Training varied with coordinator but generally included explaining the study objectives, sampling design (see next section), and survey protocol to field interviewers; educating them on species of interest; and practicing interviews to highlight and resolve aspects of the survey that were potentially confusing (sensu White et al., 2005). Interviewers were instructed to seek permission from the leaders of fishing communities before interviewing fishermen. They were also instructed to preface each survey with a statement explaining the purpose of the survey and to assure fishermen that interview data were confidential (sensu Fowler, 2009). Interview forms were designed to be filled out separately for each type of gear that fishermen used. Illustration cards of marine mammals and sea turtles known or expected to occur in the study areas were used to help fishermen identify species caught. Coordinators were also asked to have interviewers take maps into the field for fishermen to describe locations of their fishing areas. Finally, coordinators were asked to summarize survey challenges encountered by interviewers in the field and to provide feedback on the survey process to help revise the study protocol for future application.

2.3. Sampling design

In most countries, the study area included the majority of the nation's coastline (Table 1). The most significant exceptions to this were Malaysia (only Sabah state included), Tanzania (only covered part of the mainland coast and excluded the island of Zanzibar), and Comoros (only two of three islands surveyed). Our general attempt to quantify marine mammal and sea turtle bycatch in each study area consisted of estimating a measure of total effort in that area and multiplying this by an average bycatch rate estimate (i.e., number of individuals taken per boat per year).

2.3.1. Fishing effort

We used total "number of boats" as our fishing effort metric for each study area as it is one of the most basic and universal metrics of fishing effort (McCluskey and Lewison, 2008). Based on difficulties we encountered in collecting data for more specific effort metrics during this study, we also believe that boat counts are the most feasible effort data to obtain reliably from rapid, low-cost surveys. Moreover, fishing effort and bycatch rates expressed in terms of more specific effort metrics (e.g., number of boat-days, number of fishing trips) can typically be reduced to values expressed in terms of boat numbers, facilitating comparison with other studies. 'Boat numbers' has been used previously as the bycatch rate denominator in interview-based research (López et al., 2003).

We sought to estimate the number of boats in a study area (e.g., region or country) by recording the numbers of boats through representative or probabilistic (random or systematic) sampling of fishing communities, calculating the average number of boats per community for the sample, and then multiplying by the number of fishing communities in the study area. Boats were counted at times of day when boats were not expected to be fishing and were recorded on the port description form. We attempted to formally stratify sampling in all countries according to size of fishing community or landing site (e.g., large, medium, and small "ports"), but lack of prior information about the number and size-distribution of landing sites in most countries made this impractical. We did, however, summarize data from each study area for several geographic strata defined *post hoc*.

2.3.2. Bycatch

We aimed to use interview data to estimate bycatch rates, expressed in terms of individuals caught per boat per year, and with separate estimates for each species of sea turtle and marine mammal. Boats are generally worked by a crew of several fishermen, any of whom were potentially subject to being interviewed, so we assumed that each fisherman's response provided an estimate of per-boat (not per-fisherman) catch. As with fishing effort our goal was to obtain bycatch data through representative sampling of fishermen and fishing communities, to permit bycatch rate estimation for each geographic stratum within a study area (country). Multiplying strata-specific bycatch rates and fishing effort would yield total bycatch estimates.

Table 1
Extent of study area and total sampling effort (occurred during 2007 and 2008) for countries in this study.

Country	Study area	Sampling duration (mos.)	Cost (US$)	Total number of sites[a] visited	Total number of surveys	Number short-form surveys	Number long-form surveys
Sierra Leone	Entire coast	2	5100	34	693	424	269
Nigeria	All eight coastal states	7	7000	54	648	378	270
Cameroon	four of five coastal regions	10	5600	23	902	657	245
Tanzania	three of five mainland coastal regions	10 days	7400	8	537	267	270
Comoros	two of three islands	2	2300	30	409	234	175
Malaysia	Sabah state	4	12,000	161	2670	2170	500
Jamaica	Entire coast	7	7700	15	274	274	45
Average		4.6	6700	46	876	629	253

[a] Definition of "site" varied across countries. In some, it was an individual landing site; in others it was a community consisting of several landing sites.

3. Results

3.1. Survey effort

Over 6100 interviews in seven countries were conducted for a total cost of approximately USD $47,000. While this does not reflect the cost of protocol development or data analysis, it does include all implementation components of the research, including training costs and most data entry. On average per country, 876 surveys from 46 sites were conducted over 4.6 months for approximately USD $6700 (Table 1). All countries completed roughly 300 surveys or more in fewer than 10 months and all except Malaysia did so for less than USD $8000.

3.2. Consistency of survey protocol and data reporting

The consistency of data collection and reporting varied across countries and data types, particularly with respect to aspects of sampling design. The distribution of sampling effort across geographic strata did not generally conform to the distribution of fishing effort (Table 2) but rather to logistical considerations such as transportation infrastructure, travel distance, locations of major port centers, and safety (i.e., avoiding areas of civil or political unrest). Representative sampling of communities and fishers (within size- or geographically-based strata) rarely occurred, in some instances due to a lack of pre-existing information to develop a robust sampling design, in others for logistical reasons (lack of roads, avoidance of unsafe areas due to political unrest), and in others due to non-adherence to protocol by interviewers. Rather, most surveys were conducted via opportunistic or convenience sampling. Interviews focused on the most accessible villages or those perceived as the most important (larger villages, those using gears most relevant to the study, etc.).

Data to quantify the number of sites or communities throughout the study area were generally not collected. This combined with non-representative sampling of communities precluded our ability to estimate boat totals for most study areas. Fortunately, for five of the seven countries (all except Sierra Leone and Nigeria), some type of boat survey data already existed in national reports or boat registries (Table 2). In Sierra Leone, information existed for the number of communities but not for average community size (number of boats), so we estimated country boat totals by dividing estimates of the number of fishermen (from pre-existing data) by average crew size estimates (based on data from our surveys). We had to rely on 1998 FAO data (FAO, 2009b) for the most recent boat-count estimates for Nigeria.

With respect to recording and summarization of particular data types, boat counts (from port description forms) appeared to be recorded consistently, but more detailed information about landing sites, e.g., size-distribution of boats and the number of different types of boats, was less reliably noted or was summarized using different metrics. Terms such as ‘landing site’, ‘community’, ‘village’, etc., were often confused or used interchangeably, so that ‘number of sites’ reported in Tables 1 and 2 are not necessarily comparable across countries (as a community could include multiple landing sites). There was general consistency in the recording and summarizing of short-form interview data (fishing gear used, bycatch incidence, numbers of turtles and mammals caught), but for fishermen using multiple gears, bycatch responses were not consistently discriminated by gear. Questions specific to long-forms (descriptions of fishing gear, temporal fishing patterns, target species) were recorded and summarized less consistently. In the few countries where interviewers took maps into the field or attempted to collect any spatial information about fishing patterns, coordinators indicated that fishermen were commonly unable to interpret maps or specify fishing locations or distances from shore where they fished.

Table 2
Number of fishermen and boats, and sampling effort, in different geographic areas of each country.

Country	Geographic Stratum[a]	Number of sites present[b,c]	Number of sites visited[b]	Number of boats[c]	Number of fishers[c]	Number of interviews
Sierra Leone	Northern	132	7	2400	10,645	116
	Western	56	20	1300	6033	376
	Southern	342	7	3200	13,801	201
Nigeria	West	147	38	77,000 for entire country	700,000 full-time; 1.2 million total throughout Nigeria	301
	Delta	192	9			168
	East	153	7			179
Cameroon	Ndian	300 throughout Cameroon coast	0	2668	9387	0
	Fako		6	1476	4908	266
	Wouri		4	1837	6484	168
	Sanaga Maritime		5	639	2415	103
	Ocean		8	715	942	365
Tanzania	Tanga	59	0	1391	7756	0
	Coast	83	4	2726	12,984	303
	D'Salaam	23	2	1039	4887	116
	Lindi	41	2	1117	5014	120
	Mtwara	27	0	1069	5606	0
Comoros	Grand Comore	44	25	2299	4500	340
	Moheli	13	5	348	1100	69
	Anjouan	17	0	1680	2400	0
Malaysia	Sabah state	179	161	7700	20,000	2670
Jamaica	North	116	6	3034	~20,000 for the country	83
	South	78	9	1918		191

[a] Strata definitions (listed north to south within country). Nigeria: West = states of Lagos, Ogun, Ondo; Delta = states of Delta, Bayelsa, Rivers; East = states of Akwa Ibom; Cross River. Cameroon strata are political divisions. Tanzania strata are "coastal regions" of the mainland. Comoros strata are islands.
[b] Definition of "site" varied across countries (individual landing site, community consisting of several landing sites).
[c] Sources for site, boat, and fisherman totals. Sierra Leone: Fisheries of Sierra Leone, 2003, this study; Nigeria: Federal Dept. of Fisheries Reports 2000, FAO, 2009b (1998 data); Cameroon: Folack and Njifonjou, 1995; Tanzania: Sobo et al., 2008; Comoros: Abdoulhalik, 1998; UNEP, 2002; Malaysia: Sabah state vessel registry, this study; Jamaica: Espeut and Grant, 1990, P. Espeut, unpublished data.

3.3. Fishing effort and gear-use characterization

For the purposes of this paper, and because of reporting inconsistencies described above, we summarize a subset of information gathered over the course of this pilot work. Across the seven countries investigated, fishing gear use was diverse but generally dominated by gillnets, which were employed by roughly 33–62% of fishing boats except in the Comoros, where simple hook-line fisheries were most commonly used (Table 3). Other common fishing methods were longlining (most common in the West African countries) and other hook-line techniques, and various applications of seine nets (beach seine, surround seine, purse seine). Trawl fishing was less common by numbers but was the dominant form of industrial fishing in several countries (e.g., Malaysia [Sabah], Cameroon, Tanzania, Nigeria).

Each study area included from at least 74 to several hundred fish landing sites or communities, and the number of active fishing boats per study area varied from roughly 4400 boats to roughly 7000–8000 boats (Table 2), although older data sources likely underestimate current boat totals because many artisanal vessels are not registered and global artisanal fishing effort has increased over the past decade (FAO, 2009a).

Common artisanal boat sizes throughout the study countries ranged from 3 to 12 m (mostly under 9 m), with small numbers of boats reaching 20 m in some countries. The prevalence of boat motorization varied across countries. Most boats in West Africa and Sabah were reportedly motorized, generally with 15–20 HP motors (some <10 HP, and up to 40–50 HP for large boats), but non-motorized boats also were common. In 1998, the percentages reportedly motorized were 0.57 in Cameroon, 0.21 in Nigeria, and 0.82 in Malaysia (FAO, 2009b). In the Comoros, 40–50% of boats were reportedly motorized, up from an estimated 16% in 1998 (FAO, 2009b). Only ~10% of marine vessels in Tanzania are motorized (Sobo et al., 2008), in comparison to a reported 5% for Tanzania's entire fishery in 1998 (FAO, 2009b). The prevalence of boat motors was not quantified in Jamaica but port descriptions suggested a broad mix of motorized and non-motorized boats.

3.4. Sea turtle and marine mammal bycatch

Although our objective was to obtain species-specific annual bycatch estimates (per-boat rates and total bycatch) for each pilot study area, in practice there were several factors that precluded estimation of bycatch. First, although species identification cards were provided during interviews, uncertainty in species identification by fishermen hindered most species-specific summaries of bycatch. Therefore, we used interview data to compile potential species lists (Table 4), but we were restricted to summarizing bycatch data at the level of major taxonomic group (cetaceans, sirenians and turtles). Second, as noted above, survey implementation was not entirely consistent across countries and did not allow for collection of statistically representative samples. Finally, for at least some countries, it was clear after survey completion that responses to the same bycatch questions varied for short-form and long-form data (Table 5). This raised concerns about response accuracy. Because of these issues, we provide simple summaries of reported bycatch information rather than extrapolate total bycatch estimates, as such estimates and associated confidence intervals would be statistically invalid under the circumstances.

Species from all taxonomic groups considered in this study were captured by fishermen in all countries. The proportion of fishermen reporting catch of sea turtles annually varied from a low of 0.06 in Tanzania to a high of 0.70 in one region in Sierra Leone (Table 5). Bycatch incidence rates varied substantially across

Table 3
Percentage of boats or fishermen employing different fishing gear types and characteristics of those gears. Percentages can add up to >100% because fishermen were surveyed for multiple gear types. Gear descriptions summarize range of reported values, as summarized by in-country coordinators.

Country	Gillnets		Beach Seine		Longlines		Handline/Hook-and-line		Trawl gear		Other	
	%	Characteristics	%	Characteristics	%	Characteristics	%	Characteristics	%	Characteristics	%	Gears
Sierra Leone	50	10–30 cm mesh, 100 m-1.5 km length, 6+ h soak	13	4–10 cm mesh, 100–500 m length, 3–4 h soak	26[a]	Up to 1000 hooks, 250 m long, 6–12 h soak	26[a]	1–3 hooks	4	5–13 cm mesh, 500 m length, 1–6 h soak	37	Purse/surround seines
Nigeria	33	4–18 cm mesh (15–25 cm for sharks), 250–1000 m length, 2–4 m depth	4	2–5 cm mesh, 250–750 m length	12	#1–12 hooks spaced 0.5–1 m, 500–1000 hooks, 0.5–1.0 km long	8	#13–#18–120 hooks	<1	Tow @ 2.5–3.0 knot; 44 mm and 76 mm mesh[b]	50	Purse seine, circle seine, stow net, cast net
Cameroon	53	No info.	<1	No info.	36	No info.	12	No info.	7	No info.	2	Surround seine
Tanzania (mainland)[c]	51	15 and 30 cm mesh, 200–1000 m length	1	No info.	4	No info.	23	No info.	<1	No info.	21	
Comoros	3	2–4 cm mesh, 15–800 m length, 3–20 m depth	0		7	Multiple (15–180) hooks, various sizes	89	1–5 hooks, various sizes	0		1	Seine
Sabah (Malaysia)	47	3–20 cm mesh, 6 m-5 km length, 1–10 m depth	3	2–3 cm mesh, 100 m length, 1–1.5 m deep, 5–8 h soak time	2	No info.	34	#6–#9 hook size, set >20 m deep	7	Tow @ 1.5–3 knot, 3–6 cm mesh, 5–35 m headrope, 2–35 m bag depths	8	Purse seine, pound net, trap, cast net
Jamaica[d]	62	4–6 cm mesh	1	No info.	6	100 m to 10 km, <50 to several thousand hooks	24	1–3 hooks	6	No info.	ND	Trammel net, troll, sprat net

[a] The Sierra Leone report grouped commercial longlines (1000 hooks) with "household use" handlines (1–3 hooks). So, the value of 26% is for all hook-line fisheries.
[b] Nigerian vessels trawl for shrimp and fish. For shrimp, mesh size is 44 mm and TEDs (turtle excluder devices) are used. For fish: 76 mm mesh with no TEDs.
[c] Tanzania data were collected as part of another study focusing on gillnet fishing, so only data for this gear were collected, but percent usage values were available from Sobo et al., 2008.
[d] Gear use percentages in Jamaica are relative to each other. Other gears used were not recorded, so % use of these gears relative to "other gears" is unknown.

Table 4
Unconfirmed species list. Sea turtle and marine mammal species reportedly captured (incidentally or intentionally) by artisanal fishermen in the sampled study areas. 'Greater than' (>) symbols indicate relative incidence rates for species in countries where data allowed this evaluation.

	Sea turtles	Ceteaceans	Sirenians
Sierra Leone	Cm, Ei, Dc, Cc, Lo	St, *Stenella* sp., Tt, Sb, *Delphinus* sp., *Globicephala* sp., *Kogia* sp.	Ts
Nigeria	Dc, Cc, Ei, Cm	No bycatch reported	Ts
Cameroon	Cm, Ei, Lo, Dc	Species not ID'd	Ts
Tanzania	Cm > Ei > Cc > Lo	Species not ID'd	Dd
Comoros	Cm > Ei > Cc	Sl > Ta > Sc > Gg; *Delphinus* sp.	Dd
Sabah (Malaysia)	Cm > Ei > Lo > Cc > Dc	Sc, Tt, *Stenella* sp.	Dd
Jamaica	Ei > Cm > Cc > Dc and Lk > Lo	Tt > *Stenella* sp.	Tmm

Species key:
Sea turtles: Cc = *Caretta caretta* (loggerhead); Cm = *Chelonia mydas* (green); Dc = *Dermochelys coriacea* (leatherback); Ei = *Eretmochelys imbricata* (hawksbill); Lk = *Lepidochelys kempii* (Kemp's ridley); Lo = *Lepidochelys olivacea* (olive ridley).
Cetaceans: Gg = *Grampus griseus* (Risso's dolphin); Sb = *Steno bradenensis* (rough-toothed dolphin); Sc = *Sousa chinensis* (Indo-pacific humpback dolphin); Sl = *Stenella longirostris*; St = *Sousa teuszii* (Atlantic humpback dolphin); Ta = *Tursiops aduncus*; Tt = *Tursiops truncatus* (common bottlenose dolphin);
Sirenians: Dd = *Dugong dugon* (Dugong); Tmm = *Trichechus manatus manatus* (Antillean manatee); Ts = *Trichechus senegalensis* (West African manatee).

Table 5
Reported bycatch incidence rates (proportion of interview respondents reporting annual capture) for sea turtles, cetaceans, and sirenians in the sampled study areas. Where two values are reported, the first is from long-form data and the second is from short-form data.

Country	Geographic Stratum[a]	Sea turtles	Cetaceans	Sirenians
Sierra Leone	Northern	0.49, 0.58	0.29, 0.69	0.08, 0.10
	Western	0.44, 0.59	0.15, 0.24	0.04, 0.06
	Southern	0.65, 0.70	0.00, 0.66	0.00, 0.27
Nigeria	All[b]	0.48	0.00, 0.00	0.18
Cameroon	Fako	0.28, 0.12	0.15, 0.07	0.02, 0.01
	Wouri	0.12, 0.07	0.00, 0.00	0.04, 0.00
	Sanaga Maritime	0.29, 0.12	0.00, 0.00	0.03, 0.07
	Ocean	0.21, 0.14	0.01, 0.01	0.01, 0.00
Tanzania	Coast	0.06, 0.08	0.03, 0.03	0.03, 0.03
	D'Salaam	0.40, 0.19	0.03, 0.00	0.004, 0.00
	Lindi	0.28, 0.29	0.05, 0.10	0.004, 0.02
Comoros	Grand Comore	0.09, 0.16	0.04, 0.02	0.00, 0.04
	Moheli	0.14, 0.03	0.00, 0.06	0.00, 0.00
Malaysia	Sabah state	0.24	0.15, 0.06	<0.01
Jamaica	North	0.12	0.00	0.01
	South	0.32	0.06	0.02

[a] See footnotes in Table 2 for strata descriptions.
[b] Nigerian bycatch data summaries were not broken down by strata.

geographic strata within individual countries, with approximately two- to five-fold differences between minimum and maximum rates reported in most countries. Of those fishermen who caught turtles, the number they reported to catch annually varied from <1 per to '>10' per year in Tanzania and Cameroon, up to 15 per year in Jamaica, 30 per year in the Comoros, 50 or 150 per year for some fishermen in Sierra Leone (for long and short-form data, respectively), and as many as 300 per year for some fishermen in Sabah. Even if a conservative value of 1 turtle per year is used for each boat reporting bycatch, then the proportion of boats per study area that reported bycatch suggests that the number of turtles caught per year may number at least in the low thousands in each country studied.

The proportion of fishermen reporting to catch cetaceans (all odontocetes) annually varied from zero in parts of several study countries to a high of 0.29 (long-form) and 0.69 (short-form) in Sierra Leone (Table 5). The high in countries apart from Sierra Leone (for either form type) was $\leqslant$0.15. A conservative estimate (again, if only 1 individual per year is captured by respondents reporting bycatch) based on these incidence rates suggests at least several hundred small cetaceans are caught in each of these countries each year. The reported incidence rate of 0.00 in Nigeria is not a credible estimate, given interview-based information from Nigerian fishermen outside of this study (Van Waerebeek, pers. comm.). This calls into question other zero rate estimates, as well.

Data summaries from five countries provided insight into which fishing gears caused the most bycatch. Gillnets resulted in the highest bycatch overall, but in some regions other gears such as seine netting and longlining also led to relatively high bycatch. In Nigeria, 71% of reported sea turtle bycatch occurred in gillnets (compared to 8–11% each in beach seine, purse seine, and longlines) even though only 33% of fishermen reported using gillnets (Table 3). Similarly, in Tanzania, all cetacean bycatch and 82% of turtle bycatch occurred in gillnets, even though only 53% of respondents were gillnet fishermen. In Cameroon, over 60% of fishermen who reportedly caught sea turtles or marine mammals did so in gillnets, compared to roughly 30% for both taxa in longlines, 5% for both taxa in beach seines, and 6% for sea turtles in surround seines. In Sabah, the annual average sea turtle take per respondent ranged from 1 to 7 (across sea turtle species) for gillnets compared to 1–16 for trawl, 1–27 for longline, 8–31 for purse seine, and 0–8 for simple hook-line fishing. Thus on a per-effort basis, other gears in Sabah may have had higher sea turtle bycatch than gillnets, but the predominance of gillnet use there (Table 3) means that gillnets probably contributed the greatest amount of bycatch overall. Fifty-eight percent of cetacean bycatch in Sabah reportedly occurred in gillnets compared to 17% in purse seine fisheries, 8% in trawls, and on 2% in beach seine and longlines. In Sierra Leone, sea turtle bycatch incidence rates across gears were similar to the proportional use of these gears, but as with Sabah, the predominance of gillnet fishing means this gear contributed the greatest amount of bycatch. Thus, 45% of reported sea turtle bycatch in Sierra Leone occurred in gillnets, comparable to the proportion of fishermen using this gear (50%). Roughly 20% of respondents catching sea turtles caught them in longlines, another 20% caught them in surround seines, 10% in beach seines, and 5% in trawls. Out of those fishermen in Sierra Leone reporting cetacean bycatch, approximately 44% reported catching them in gillnets, compared to 21% in surround seines, 16% in longline, 13% in beach seines, and 6% in trawls. Sirenian bycatch occurred almost exclusively in gillnets (but was also reported for hook-line gear in the Comoros and Cameroon). However, direct harvest of West African manatee – via use of nets, traps, and harpoons – was also voluntarily reported throughout West African study areas. In Sierra Leone, 12% of all respondents reportedly captured approximately 2100 manatees, with a single respondent saying he had killed 500. Interviewees in Nigeria and Cameroon reported a total of 180 and 290 manatee kills, respectively. Actual numbers caught throughout the countries are presumably much higher. Bycatch of dugongs (in Tanzania, Comoros, Sabah) and Antillean manatees (Jamaica) was rare (Table 5), with many fishermen in range countries indicating this as a once in a lifetime event. Sirenian take in most countries was described as a localized phenomenon (e.g., associated with specific lagoons, river mouths, etc.); therefore any approximations of the magnitude of total takes based on survey data were not possible for this study since reported incidence rates cannot be extrapolated throughout the study areas.

4. Discussion

4.1. What do rapid interview assessments tell us about bycatch?

Data from our pilot study suggests that high bycatch of marine mammals and sea turtles are the rule rather than the exception in the world's artisanal fisheries. The apparent magnitude of cetacean and sea turtle bycatch in each country was comparable to the alarming numbers from recent case studies of other artisanal fisheries (Lee Lum, 2006; Peckham et al., 2007; Mangel et al., 2010). Bycatch occurs particularly frequently in gillnets, but other fishing gears may contribute substantially to odontocete and sea turtle bycatch in some areas. Some fishing gears, such as artisanal seine nets, have not frequently been described as substantial sources of bycatch. For the West African manatee, intentional harvest appears to be more severe than bycatch as a mortality source.

Apart from these general conclusions, the inconsistencies in sampling and survey implementation precluded us from deriving statistically valid bycatch estimates or comparing bycatch levels across areas and species. We will address these issues in future improvements to the interview protocol and survey design. Jones et al. (2008) demonstrated that rapid assessment interview data has the potential to provide accurate quantitative information, but whether this holds true for protected species bycatch requires further study. Memory decay and biased response by interviewees contribute substantial error to survey data (Bernard et al., 1984; Bradburn et al., 1987; Fowler, 2009; Gomm, 2004). Fishermen's memory-related errors may be higher for relatively unimportant events such as capture of non-target species than for those that are more important to their livelihood (Fowler, 2009; Young et al., 2006). Target catch (or incidental catch of a target species) is often over-estimated from interview or other self-reporting data from fishermen (Walsh et al., 2005; Lunn and Dearden, 2006; Young et al., 2006), whereas bycatch of discarded or protected species has been under-reported, presumably in part because of perceived negative consequences of accurate reporting (e.g., Walsh et al., 2002; NMFS, 2004). We might therefore suspect marine mammal and sea turtle bycatch to be under-reported in many countries, particularly in areas where such bycatch is prohibited. Fishermen may be more likely to accurately report their capture and use of marine mammals and sea turtles where they are not protected or where protection is not enforced (sensu Gros, 1998). It is obvious from the large bycatch numbers reported in our study that many fishermen were willing to speak openly about capturing these taxa. It also possible that fishermen could over-report bycatch to impress interviewers, comply with perceived interviewer attitudes, or if they perceive opportunities to attract outside investment to their communities (Sheil and Wunder, 2002; Gomm, 2004). These uncertainties underscore the need for in-depth research to independently validate interview-based estimates (Gavin and Anderson, 2005; Gilchrist et al., 2005; White et al., 2005; Jones et al., 2008; Anadón et al., 2009). Nevertheless, our results indicate promise in assessing bycatch over a large geographical area, and we provide concrete recommendations below to address the caveats stated above.

4.2. Can the protocol be implemented quickly and cost-effectively?

Yes. In less than 2 years we designed and implemented the protocol at a relatively low cost. For approximately USD $47,000, the protocol was implemented in seven countries on four continents, conducting a total of 6133 surveys. The cost of future implementation of this protocol will be higher than that of the present pilot effort for two reasons. For regional studies that will involve multiple teams from different countries, extra effort will be required by study planners to ensure consistency of protocol implementation and completeness of data collection (see next section). This will likely require site visits by principal investigators to conduct intensive workshops with local teams on the ground for the purpose of thoroughly explaining the study objectives, methodology, and sampling design, and for providing adequate training for administering interviews. In addition to the workshops, routine follow-up exercises will be required (on location or remotely) to maintain protocol consistency, address problems along the way, and ensure completeness and accuracy of data collection and recording. Secondly, more time and effort will be required during the implementation period to achieve appropriate sampling design. In the current pilot study, communities and fishermen were generally sampled opportunistically, thereby limiting inferences that might have otherwise been obtained through extrapolation of estimates based on a probabilistic sampling design.

4.3. Recommendations for improved surveys

Ecologists are increasingly recognizing the value of social science methods for conducting conservation research (Drew, 2005; White et al., 2005; Lowe et al., 2009). This is leading to more interdisciplinary collaboration, as well as to more direct forays by ecologists into social science realms (Lowe et al., 2009). Our study is an example of the latter, and we described several obstacles to our research objectives that may have been better dealt with had we collaborated with social scientists directly from the outset. We suspect these issues are common for natural scientists working with human subjects, but they seem to be rarely acknowledged in the biological literature. Given our experiences, an interdisciplinary team of natural and social scientists could more effectively design and implement interview-based research. Such collaborations would strengthen research methodologies and improve the quality of information collected and also have the potential to shape the research itself more effectively for conservation (Mascia et al., 2003; Campbell, 2005; Fox et al., 2006; Phillipson et al., 2009).

We convened a *post hoc* workshop to solicit feedback on this study and to provide recommendations for revising our protocol for future implementation. Based on this and our experiences, we offer suggestions in six key areas for improving future research. These are not fully comprehensive; readers should also consult expert references on social survey methodology (e.g., Gomm, 2004; White et al., 2005; Fowler, 2009).

4.3.1. Sampling Design

Extrapolating bycatch estimates for a target population (e.g., for an entire fishery, or all fisheries in a country, etc.) requires that data be obtained from representative or probabilistic samples of that population, obtained from random or systemic sampling (simple or stratified, the latter being preferred if prior information exists upon which to base the stratification). Data from non-probabilistic methods such as opportunistic or convenience sampling (e.g., visiting whichever fishing communities seem most important or easiest to get to, or interviewing whichever fishermen are present at the docks) may not produce statistically valid estimates because they cannot be generalized to the target population. Observations also should be independent (e.g., one record per fishing vessel), which may require extra planning to insure that multiple fishermen from the same fishing crew are not sampled. In practice, truly probabilistic sampling design may be difficult to implement over large undeveloped areas in a rapid low-cost manner (as in this pilot study). Transportation may be difficult; complete lists of fishing communities and their locations may not exist; there may be little available information about those communities; and no accurate boat registers may exist from which to sample fishermen. Multistage sampling – and area probability sampling in particular – may be useful under these circumstances (see Fowler, 2009).

4.3.2. Questionnaire format

Closed-question surveys have generally be recommended when the goal is to maximize accuracy of factual information obtained through an interview, especially if quantification is desired (Huntington, 2000; Gomm, 2004; White et al., 2005; Fowler, 2009). We used this format, which facilitates standardization of surveys administered by multiple interviewers or over large areas, and reduces uncertainty in questions and answers for both interviewer and interviewee. Short surveys (<30 min) have been recommended to reduce non-response rates (White et al., 2005), and since many fishermen are time-limited (Close and Hall, 2006). However, adequate time should be devoted to each question (maximize the ratio of survey time to number of questions), as this improves memory recall of an event (Bradburn et al., 1987). It may be useful to include some open-ended questions (those not needing to be quantified); this could improve interviewees' memory recall for factual questions and yield unanticipated insights (Huntington, 2000). Based on these principles, we recommend a modified hybrid of the two questionnaire lengths we used (Appendix 2). The modified form is closer to our "long" questionnaire, which was designed to take 20–30 min, similar to the limit recommend by White et al. (2005).

4.3.3. Improving data reliability

Although some factors affecting the reliability of questionnaire data cannot be addressed with improved methodology (e.g., fishermen's memory accuracy), steps can be taken to assess and improve the reliability of response data to a large degree. Questions and answer choices should be simple, straightforward, worded unambiguously, presented to fishermen in a standardized way (e.g., read to fishermen exactly as written on the form), and pre-tested for clarity in all study areas. These will help with foreign language translation and interpretability by fishermen from different educational and cultural backgrounds (Gomm, 2004). Translators assisting interviewers should have fisheries backgrounds to improve translation of unavoidable jargon and interpretation of fishers' responses (Lunn and Dearden, 2006). Allowing for "I don't know" or "not sure" answers (Gros, 1998) is preferable to collecting misinformation from fishermen who are just trying to be cooperative (Gomm, 2004). In accordance with these principles, several questions used in our pilot study (Appendix 1) have been modified for future application (Appendix 2).

Shorter temporal sampling frames will yield more accurate data, since memory recall degrades with time. Working backward through time (i.e., starting with questions about more recent events) improves accuracy compared to working forward from the past (Bradburn et al., 1987). The questionnaire could be augmented with questions about longer time frames, however, in hope of gaining new insights about historical trends and issue development (Neis et al., 1999; Sáenz-Arroyo et al., 2005; Anadón et al., 2009). Our questionnaires were designed to collect quantitative information about the most recent year of fishing, but we have modified question wording to be more explicit in our revised questionnaire, and we have added questions about historical trends.

The use of photo or illustrated identification cards describing different fishing gears and species of study interest is important, since the associated terminologies will differ across communities, languages, and education and literacy levels. We used photo ID cards, but we recommend pre-testing identification cards for their usefulness and comprehensiveness, which we did not do originally. We also recommend including a few 'test' species that do not occur in the study system could be included on species identification cards to filter out unreliable records (i.e., those in which fishermen report catching these species); this represents an additional modification to our original approach.

Non-response information (e.g., proportion of fishermen who refused to participate in the survey) should be collected and reported; this can provide a measure of how representative the sample is of the target population (Gomm, 2004; White et al., 2005; Groves and Peytcheva, 2008; Fowler, 2009). Because high non-response rates can yield biased information, attempts should be made to minimize non-response. Suggestions that were implemented in our study include using short simple surveys and approaching fishermen when they are more available to talk. Additionally, it may be helpful to make the survey relevant to their interests and concerns (Hall et al., 2007; Campbell and Cornwell, 2008), and to assure them of their confidentiality and that the risk of consequences from participating is low. Fishermen may also be more likely to participate (and to give more accurate information) if the interviewer is native to the study area (or otherwise known and trusted). Most field interviewers in our study were native to study areas or worked with native translators, although in some cases interviewers were non-natives working for local organizations.

Several authors have suggested that it is important to identify appropriate experts to interview so that the qualify of data is maximized (Berkes et al., 2001; Davis and Wagner, 2003; Anadón et al., 2009). Indeed, not all fishermen are equally expert informants; for example, data from Sierra Leone in our study suggested that village elders (who were preferentially administered long questionnaires) provided different information than other fishermen (who were administered short questionnaires) (Table 5). Therefore, it may be wise to limit the sampling pool to, for example, boat owners (rather than any crew member), community leaders, or fishermen recommended by community leaders (e.g., Lunn and Dearden, 2006). Of course, it is important to consider how this affects the representativeness of the sample. If the sample pool is not narrowed in such a way, then it may be wise to at least record basic personal information about each fisherman that will likely reflect their level of expertise (e.g., their age, how long they have been fishing, whether they own a boat). Our questionnaire has been modified to gather this type of information (Appendix 2), which may be used to assess whether response data varied with these attributes.

Other strategies for gauging data quality include assigning a reliability score to each survey and collecting ancillary data that may correlate with accurate and honest reporting. Gros (1998) assigned reliability scores to surveys based on the apparent precision and consistency of information provided and the level of cooperation and interest by the fisherman; then only data receiving fairly high reliability scores were used in analyses. Useful ancillary data could also come from asking fishermen whether marine mammals and sea turtles are caught by *other* fishermen, or are legally protected in the area and whether that protection in enforced; whether the fishermen have been interviewed before on a related topic; whether any conservation or management-related projects are present in the community; or any other questions that could indicate their awareness of bycatch as a conservation issue or of their motivations to be forthright. Focus groups might be useful for obtaining such information before surveys are administered in a study area (Gomm, 2004). The revised protocol (Appendix 2) incorporates some of these strategies. Carcass surveys on beaches and around town garbage disposal sites may also provide indices of bycatch occurrence and human utilization (e.g., Peckham et al., 2008).

4.3.4. Mapping fishing and high bycatch areas

Interview data have been used to map artisanal fisheries areas. Successful case studies have followed intensive planning and effort that typically consists of in-depth interaction with relatively educated fishermen (e.g., via scheduled group interviews or focus groups that sometimes include natural resource professionals), pre-evaluation of different maps for their usefulness (or at least using multiple types of maps) in the field, and ideally visiting fishing areas with GPS units to record location data (e.g., Aswani and Lauer, 2006; Close and Hall, 2006; Hall and Close, 2007; Daw, 2008; De Freitas and Tagliani, 2009). Such protocols may be impractical as part of a rapid questionnaire framework, and our simpler mapping efforts were not successful.

4.3.5. Ethics

First and foremost, researchers should ensure that surveys do not harm voluntary participants. Many ethical issues are involved (Gomm, 2004); among the most fundamental are ensuring that respondents are well informed about what they are consenting to participate in, and that their confidentially is protected. Fowler (2009) provides useful checklists for ensuring that these two issues are satisfactorily addressed. Our initial protocol and revised questionnaire included verbage to address these concerns, but individual researchers should ensure their protocols do not violate these ethics. Researchers should also consider how the outcomes of their work may ultimately affect participants' lives, for example by affecting policy, public perceptions, or various forms of inequalities (Silver and Campbell, 2005; Shackeroff and Campbell, 2007; Brook and McLachlan, 2005).

4.3.6. Training

Interviewers can affect the quality of data collected and therefore require training to understand and properly implement the statistical sampling design; maximize the clarity and consistency with which they ask questions and record answers; appear neutral so as to minimize influence on fishers' responses; and to assure fishermen that the risk of participating in the research is minimal (Gomm, 2004; Jones et al., 2008; Fowler, 2009). The latter point is especially important given that marine mammal and sea turtle bycatch may be taboo or even illegal in some areas and that rapid large-scale assessments may not afford interviewers the time to build trusting relationships within study communities (Gavin and Anderson, 2005). Researchers also have an ethical obligation to ensure that interviewers are fully informed about the research so they do not inadvertently mislead fishermen (Fowler, 2009). Well informed interviewers will be better able to recognize and clarify strange responses during interviews and assess the reliability of information from each interviewee (sensu Gros, 1998). In our pilot study, all interviewers received training, but this was left to in-country coordinators, which resulted in data quality that was inconsistent across countries and difficult to assess. We will incorporate more comprehensive and standardized training across research teams in future study.

4.3.7. Presentation of methodology at publication

Transparency of survey methodology promotes study replication and standardization, and allows others to better evaluate the quality of research. Researchers should include a copy of the questionnaire and provide sufficient detail on all aspects of data collection discussed above. These include sampling design and participant selection methods; non-response information; ethical measures taken; information about interviewers, training and question pre-testing; calculations for estimating sampling error; and any attempts to validate or otherwise assess the reliability of information given by interviewees. See Fowler (2009) and White et al. (2005) for additional reporting suggestions.

5. Conclusions

Rapid interview surveys allowed us to collect considerable information about the characteristics of artisanal fisheries and bycatch of over broad geographic areas at a relatively low cost. These surveys provided evidence of the widespread nature of marine mammal and sea turtle bycatch in artisanal fisheries; such a finding could not have been accomplished in such a short time period using observer programs without a much greater investment of time and money. However, we encountered challenges that preclude us from using our initial data to make comparative analyses of the frequency of bycatch across species, regions, or gear types. We have been forthright in our disclosure of challenges that resulted from training oversights and imperfect execution of social science methods, because we suspect these issues may be common for other natural scientists working in fisheries and we hope our example helps improve future research.

Based on our experience and expert input, we have prescribed methodological improvements to interview survey protocols for studying bycatch in artisanal fisheries, and we believe study-specific modifications our questionnaire (Appendix 2) will provide high quality human response data. We feel this approach has the potential to become an important conservation tool for studying the bycatch of large vertebrates, as it has for understanding other aspects of artisanal fisheries. This protocol, however, is not intended as a substitute for empirical research to estimate bycatch and its population-level effects on marine wildlife. There are inherent limitations in the accuracy of even the most carefully collected human response data, and the reliability of such data for conducting comparative bycatch analyses is yet to be determined. Independent validation will be required to describe the link between truth and reported bycatch information, and whether the correspondence between these can be predicted under different cultural, environmental or socio-economic circumstances.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2009.12.023.

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