REPORT

Positive Interactions Between Irrawaddy Dolphins and Artisanal Fishers in the Chilika Lagoon of Eastern India are Driven by Ecology, Socioeconomics, and Culture

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Abstract In human-dominated landscapes, interactions and perceptions towards wildlife are influenced by multi-dimensional drivers. Understanding these drivers could prove useful for wildlife conservation. We surveyed the attitudes and perceptions of fishers towards threatened Irrawaddy dolphins (*Orcaella brevirostris*) at Chilika Lagoon India. To validate the drivers of fisher perceptions, we : (1) observed dolphin foraging behavior at stake nets, and (2) compared catch per unit effort (CPUE) and catch income of fishers from stake nets in the presence and absence of foraging dolphins. We found that fishers were mostly positive towards dolphins, believing that dolphins augmented their fish catch and using culture to express their perceptions. Foraging dolphins were observed spending half their time at stake nets and were associated with significantly higher catch income and CPUE of mullet (*Liza* sp.), a locally preferred food fish species. Wildlife conservation efforts should use the multidimensional drivers of human–wildlife interactions to involve local stakeholders in management.

Keywords Human–wildlife interactions · Fisher perceptions · Dolphin behavior · Fisher livelihoods · *Orcaella brevirostris* · Fish catch

INTRODUCTION

Conservation is becoming an increasingly important priority in the developing tropics (Adams et al. 2004), and balancing conservation needs with human livelihoods is often the

principal challenge (Sanderson and Redford 2003), particularly where the human–wildlife interface is large (Woodroffe et al. 2005). Managing this interface requires a clear understanding of local perceptions underlying human–wildlife relationships. These perceptions may be complex and multidimensional and are likely driven by experiential, ecological, socioeconomic, and cultural factors (Infield 2001; Evely et al. 2008; White et al. 2009; Dickman 2010; Peterson et al. 2010). Together the dynamic interplay of these factors influences local behavior towards wild species, with significant implications for the management of wild species and the ecosystems they inhabit.

Local community perceptions and behavior towards wild species are often disproportionate to the directly measureable costs and benefits of human–wildlife interactions (Dickman 2010; Peterson et al. 2010). For instance, the negative attitudes of fishers towards otters in Portugal and seals in South Africa often leads to these animals being killed, although the extent of economic damage they cause to the fishery appears not to warrant this extreme reaction (Wickens 1996; Woodroffe et al. 2005; Freitas et al. 2007). Similarly, the reaction of people towards sharks is disproportionate to the actual risk of being “attacked” (Neff 2011), a reaction that has been attributed in part to stereotypes generated by movies like “Jaws” (Harrison and Cantor 1999). By contrast, many traditional communities ascribe considerable value to wild species both for the resources they provide (Garibaldi and Turner 2004), as well as the potent cultural symbols and totems they represent (Passariello 1999; Telesco and Hall 2002).

Local perceptions and worldviews are based on experience, and may be influenced by multiple ecological, socioeconomic, and cultural drivers. People living close to or within natural spaces view these areas not merely as biologically diverse and physical landscapes, but also as

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“cultural constructions”, often filled with strong symbolic significance (Infield 2001). Such cultural constructions, are a consequence of the historical accumulation of abstract environmental information, and form the basis of traditional ecological knowledge, religious, and belief systems (Berkes 2008). For instance, nature conservation is an important part of Buddhist culture and religion, and greatly influences the worldview of people in Bhutan (Rinzin et al. 2009). Hence multiple drivers shape the experience, worldview and behavior of local communities interacting with wild species and spaces (Evely et al. 2008).

Attempts to understand human–wild species interactions, therefore, need to be multidimensional and interdisciplinary (Evely et al. 2008). Such an approach is necessary in order to appreciate the motivations and drivers behind the attitudes of local people and the capacity for local stakeholders to accept wild species with which they share common spaces (Carpenter et al. 2000). Appreciation of this approach has been slow to enter management philosophy, yet is vital for a more holistic and effective conservation of the human–wildlife interface.

We examine the interaction between the threatened Irrawaddy dolphin (*Orcaella brevirostris*) and artisanal fishers at Chilika, a brackish-water lagoon in the state of Odisha, on the east coast of India. In the lagoon, both dolphins and local fishers overlap in their use of space and resources. The Irrawaddy dolphin, is a globally vulnerable species (IUCN 2012); at Chilika, the population comprises approximately 150 individuals and likely meets the criteria for listing as “critically endangered” (Sutaria and Marsh 2011). Dolphin foraging overlaps closely in the lagoon with areas that fishers use to deploy their gear, as the animals track much of the same fish and invertebrate resources as local fishers. Dolphins are often seen feeding at fishing nets, particularly at permanently installed stake nets.

Our broad research aim was to investigate the nature of fisher attitudes towards Irrawaddy dolphins in Chilika Lagoon, and to test whether fisher perceptions were influenced by their community background or group, and by the probability of them encountering dolphins while fishing. Our research objectives were to explore the drivers of fisher perceptions by: (1) observing dolphin behavior in the presence of stake nets; (2) evaluating the influence of dolphins on (a) the fish catch biomass caught by stake nets, (b) fisher income from stake net catches; and (3) characterizing the cultural drivers of fisher perceptions that underlie this dolphin–fisher interaction.

MATERIALS AND METHODS

Study Area

Chilika Lagoon, Odisha, is a brackish-water lagoon on the east coast of India (19°28'N–19°54'N, 85°05'E–85°38'E)

covering an area between 906 and 1165 km² (Fig. S1 in Electronic Supplementary Material). The lagoon was declared a Ramsar site in 1982 (Ramsar 2002) because of its high avifaunal and fish diversity (Ghosh et al. 2006). Its high productivity supports fishing communities living in some 150 fishing villages around the lagoon (Nayak and Berkes 2010). The lagoon has a population of resident Irrawaddy dolphins. This study was conducted in the “Outer Channel” of the lagoon, which corresponds to the area with the highest dolphin density (Pattnaik et al. 2007) and is used by a high density of fishers (Sutaria 2009). Within the Outer Channel, dolphin foraging overlaps considerably with major fishing zones, and dolphins are often seen feeding at fixed stake nets (personal observations).

Fisher Attitudes and Perceptions Towards Dolphins

We conducted semi-structured questionnaire surveys in 30 villages ($n = 299$ interviewees) from 15th January to 5th June 2008, around the “Outer Channel” region, to assess the attitudes and perceptions of fishers towards Irrawaddy dolphins. Surveys were based on pilot informal group discussions conducted with fishers. Participants within the village were chosen opportunistically. However, villages at Chilika are organized strictly along community lines and are homogenous (Sekhar 2004; Nayak and Berkes 2010), so we conducted surveys by walking through the whole village to ensure that respondents were systematically sampled across the spatial extent of the village. Questionnaire surveys comprised both closed- and open-ended questions (Huntington 2000), were administered accompanied by a translator from the local community, and were transcribed directly in the field. Responses were recorded on a questionnaire form which was maintained for our records. We analyzed the responses using quantitative and qualitative research methods, respectively (Table S1 in Electronic Supplementary Material).

Our survey comprised two closed-ended questions asking fishers to identify any “animals” in the lagoon that potentially benefitted or harmed fishers (Table S1 in Electronic Supplementary Material). This approach ensured that respondents did not assume a priori that they were being questioned about dolphins, and clarified that respondents understood that questions specifically regarded their perception towards an animal. Responses to closed-ended questions were added for each respondent to provide an “attitude score” which ranged between -1 and $+1$ (where -1 to less than 0 were negative scores, 0 was neutral, and scores greater than 0 to $+1$ were positive).

We surveyed fishers belonging to both traditional and non-traditional fishing communities, who had both high and low probabilities of fishing alongside dolphins. “Traditional” fishers were defined as those whose traditional livelihood was fishing, whose families had been extracting

resources from the lagoon for more than two generations, and who traditionally had tenure rights to extract resources from specific areas of the lagoon surrounding their villages (Sekhar 2004; Pattanaik 2007; Nayak and Berkes 2010). “Non-traditional” fishers were new entrants, who traditionally had other livelihoods, whose families had entered the fishery for less than two generations, and did not have traditional tenure rights to extract resources from the lagoon (Sekhar 2004; Pattanaik 2007; Nayak and Berkes 2010). Traditional and non-traditional villagers were therefore distinct in terms of their background, identity, heritage, community, and experience of fishing in the lagoon, alongside dolphins. Villages surveyed were strictly separated according to community type but nevertheless, each respondent was asked to confirm his or her community identity. Respondents were provided with a map and asked to identify their fishing grounds and where they thought dolphins could be encountered. We later classified respondents into fisher groups (traditional and non-traditional) based on the above criteria, and according to their probability of encountering dolphins while fishing (high and low), based on where fishers said their fishing grounds were, and on the known spatial distributions of the dolphin population (Sutaria 2009; personal observations).

The effect of fisher group and probability of encountering dolphins on cumulative attitude scores of fishers were analyzed using a two-way ANOVA, with the individual attitude score as the dependent variable, and fisher group (traditional or non-traditional) and probability of encountering dolphins (high or low) as fixed categorical variables. We checked that the assumptions of the ANOVA were fulfilled. Tukey’s test for unequal N was conducted for post hoc results, with Bonferroni corrected p values.

We qualitatively analyzed positive perceptions, oral histories, anecdotes, rituals, and mythologies related to the Irrawaddy dolphin, documented in survey responses to the open-ended questions. We focused on positive perceptions because negative perceptions were few (10 % of respondents had negative perceptions, themes, and quotes given in Table S2 in Electronic Supplementary Material), and neutral perceptions lacked detail. Responses were analyzed by extracting themes commonly expressed by fishers that referred to positive human–dolphin interactions, and how fishers perceived dolphins to benefit them (Table 1). Some fisher responses were classified into more than one theme. We listed the total number of respondents that expressed each theme, along with examples of opinions articulated and values attributed within each theme (Table 1).

Dolphin Foraging at Stake Nets

We conducted behavioral observations on dolphins from 14th January to 4th April 2008. Observations were divided

equally between areas within 50 m of fixed stake nets and open waters. For each observation, the GPS location, time at the start and end of each encounter, and dolphin group composition were recorded. Dolphin behavior was recorded by continuous sampling (Altmann 1974) of focal groups defined as individuals within 10 m of one another and usually performing the same behavior. From these observations, we calculated the proportion of time that dolphins spent traveling, resting, milling, socializing, and foraging (Table 2).

We conducted detailed observations of dolphin surface behavior, with a specific focus on foraging. Dolphin surface foraging behavior was classified into four strategies: (1) open-water foraging defined as a foraging strategy adopted by individual dolphins in open waters, more than 50 m away from stake nets and which did not fall into any other foraging strategy, (2) barrier-foraging at stake nets as a strategy performed within 50 m or less of fixed stake nets, in which Irrawaddy dolphins distinctly used stake nets to aid their foraging, (3) mud-plume foraging in which the dolphins created plumes of mud in the water, which they use to catch fish (Lewis and Shroeder 2003), and (4) cooperative foraging wherein a group of six to 11 dolphins less than one body length from each other coordinated to herd fish into a ball before feeding on them (Gazda et al. 2005).

Effect of Dolphin Foraging on Stake Net Catch Biomass and Income

We examined the fish catch harvested from stake nets in a random sample of locations across the “Outer Channel” region from 2008 to 2010, both after dolphins were observed or known to be foraging at stake nets, and in the absence of dolphins. The species and numerical composition of the fish catch were recorded. Scaled digital photographs of the catch were used to measure standard lengths of each fish (L) using Image J (Ferreira and Rasband 2011). The biomass of the catch was calculated using the standard length–weight relationship $W = a * L^b$, where the constants a and b for each species were obtained from FishBase (Froese and Pauly 2011). Each fisher was asked to provide information regarding his fishing effort (the total duration of time for which the net was set) and thus we calculated the catch per unit effort (CPUE) for each catch, by dividing the biomass by the number of hours for which the net had been set. CPUE for each of the main components of a catch was also calculated. Species or species groups that: (1) made up more than 5 % of the total catch biomass sampled in each of the 3 years, and (2) were caught more than once a year, were considered as main components of the catch. In addition, we included tiger prawns (*Penaeus monodon* and *Penaeus semisulcatus*) as a main catch component,

Table 1 Emergent themes reflecting positive fisher perceptions towards dolphins, number of respondents, values attributed to each theme, and illustrated examples within each theme

Theme, no. of respondents	Value type	Illustrated example
Dolphins helped fishers to catch fish, $n = 205^a$	Utilitarian and cultural/mythical	<p>“Dolphins help fishermen by herding fish from deeper waters into nets during the feeding process” (1 trad, high respondent)</p> <p>“Dolphins help us, especially when we used the <i>Khaadi jaal</i>, 20 years ago. Fishermen called out to dolphins that would drive fish into nets” (1 trad, high respondent)</p> <p>“If dolphins die, fishermen will suffer, as fishing is impossible without them” (1 trad, high respondent)</p> <p>“If it (the dolphin population) increases, it is good for fish productivity” (1 trad, high respondent)</p> <p>“If it (the dolphin population) increases, it is good for fishing, which helps increase income” (1 trad, high respondent)</p> <p>“(before fishing) we pray to goddess <i>Harchandi</i>, and she sends dolphins to help fishermen catch fish” (1 trad, high respondent)</p>
Dolphins provided fishers with other economic benefits, $n = 32$	Utilitarian	“Dolphins are good for tourism” (1 non-trad, high respondent)
Dolphins benefited fishers (unspecified), $n = 26$	Unspecified	Fishers stated their opinion, but could not substantiate their belief with any explanation
Dolphins were beautiful/gentle creatures, $n = 16$	Cultural/mythical and aesthetic	<p>“Dolphins add beauty to Chilika” (1 non-trad, low respondent)</p> <p>“The dolphin is a <i>buhashani magar</i>” (1 non-trad, high respondent)</p>
Dolphins helped reduce other threats, $n = 3$	Utilitarian	“Dolphins help fishermen by scaring away sharks and other fish that break nets” (1 trad, high respondent)
Dolphins protected/rescued fishers, $n = 2$	Utilitarian and cultural/mythical	“My boat was sinking, so I prayed and dolphins came to rescue me” (1 trad, low respondent)

Trad traditional fisher, *non-trad* non-traditional fisher, *high* high probability of encountering dolphins, *low* low probability of encountering dolphins, *Khaddi jaal* a cotton-filament drag net, *Goddess Harchandi* a female deity is the embodiment of Mother Earth, *Buhashani magar* “bride shark” in Oriya (the local language), and refers to the gentle nature and large size of the dolphin

^a The total number of respondents that expressed each theme

Table 2 Descriptions of behavioral states performed by Irrawaddy dolphins at Chilika Lagoon and approximate proportion of time spent in each of them

Behavioral state	Description	Proportion of time for which observed (%) ^a
Foraging	Distinct hunting of prey, indicated by prey being pursued and/or jumping out of water, being flung/thrown, and/or seen in the mouth of the dolphin	70
Traveling	Moving steadily in a particular direction	16
Milling	Moving in an undirected fashion	14
Socializing	Distinct interactive behavior between two or more individuals	<1
Resting	Stationary or moving slowly at the surface of the water	0

^a Total observation time = 28 h, including 22 days of observation, spread over 3 months

whenever they occurred, because of their high economic value. The main components of a catch therefore consisted of small prawns and shrimps, mullet (*Liza* sp.), tiger prawns (*P. monodon* and *P. semisulcatus*), and the remaining catch species, which were combined and classified as the “remainder” of the catch.

Fishers were asked to estimate the total price of each catch based on their knowledge of current market prices, and were questioned to confirm the presence or absence of

foraging dolphins at the nets at the time of fishing, supplementing our personal observations of the same. Price estimates were cross-verified using local market surveys.

We analyzed fish catch data using restricted maximum likelihood (REML) mixed models (Piepho et al. 2003), with: (1) total CPUE, (2) CPUE of each of the main catch components, and (3) gross catch income (per unit effort) as the respective dependent variables, and with dolphin presence (absent or present) as a fixed categorical variable and

year (2008, 2009, or 2010) as a random categorical variable. Data were transformed to conform to the assumptions of mixed models.

RESULTS

Fisher Attitudes and Perceptions Towards Dolphins

The average attitude score of fishers towards dolphins ranged from neutral to positive (i.e., average scores were from 0 to +1, Fig. 1), although few individual attitude scores of fishers were negative towards dolphins. Both fisher group ($F = 16.66$, $df = 1$, $p < 0.01$) and the probability of encountering dolphins ($F = 38.32$, $df = 1$, $p < 0.01$) were associated with significantly higher attitude scores of fishers towards dolphins, as indicated from our ANOVA results. The interaction between the two factors was not significant (two-way ANOVA, $F = 1.97$, $df = 1$, $p > 0.01$). As indicated from our ANOVA post hoc results (Fig. 1; Table S3 in Electronic Supplementary Material), on average, traditional fishers with a high probability of encountering dolphins were significantly more positive towards dolphins when compared to those who fished in areas with a low probability of encountering dolphins or non-traditional fishers.

Responses to open-ended questions aligned along six positive themes, reflecting the perceptions of fishers

towards dolphins, and included: (1) dolphins helped fishers catch fish ($n = 205$, 69 % of respondents), (2) dolphins provided fishers with other economic benefits ($n = 32$, 11 % of respondents), (3) dolphins benefitted fishers in an unspecified way ($n = 26$, 9 % of respondents), (4) dolphins were beautiful/gentle creatures ($n = 16$, 5 % of respondents), (5) dolphins helped reduce other threats ($n = 3$, 1 % of respondents), and (6) dolphins protected/rescued fishers ($n = 2$, 1 % of respondents) (Table 1). Our results indicate that a majority of fishers surveyed (69 %) expressed the belief that dolphins helped them catch fish, supporting this assertion with detailed descriptions linked to utilitarian, cultural, and mythical values (Table 1). For example, one traditional fisher with a high probability of encountering dolphins said:

“(before fishing) we pray to goddess *Harchandi*, and she sends dolphins to help fishermen catch fish.”

Table 3 summarizes the proportions of responses of traditional and non-traditional fishers with low and high probabilities of encountering dolphins who expressed positive perceptions included in each of the above themes.

Dolphin Foraging at Stake Nets

The dolphins spent up to 70 % of the 28 h that they were observed, foraging (Table 2) and 50 % of their foraging time (19.5 h) barrier-foraging at stake nets (Fig. 2a). Dolphins were observed to herd fish from deeper channels towards the stake nets and used the nets as a physical barrier against which they caught the fish (Fig. 2b–d).

Effect of Dolphin Foraging on Stake Net Catch Biomass and Income

REML results indicate that the average CPUE of stake nets was not associated with dolphin foraging (Table 4; Table S4 in Electronic Supplementary Material), and suggests that dolphin foraging does not influence fish catch volume. However, the presence of dolphins was significantly associated with a higher average CPUE of mullet (*Liza* sp.) in nets compared to nets sampled in the absence of dolphins (Table 4, Table S4). There was, however, no significant association between dolphin presence and the average CPUE of tiger prawns, smaller prawns and shrimp, or of the “remainder” of the catch (Table 4). The average catch income per hour of effort was significantly higher when dolphins foraged at nets and was more than double, each year, when compared to the corresponding catch income in the absence of foraging dolphins (Table 4; Table S4).

Fig. 1 Attitude scores (mean $\pm$ SE) of fishers towards Irrawaddy dolphins at Chilika Lagoon, India varied between traditional and non-traditional fishers and their probability of encountering dolphins. The most positive group was traditional fishers who encountered dolphins frequently (a), and was significantly more positive than the attitudes of all other groups (b). Statistical significance is at $p < 0.008$ using Bonferroni correction

Table 3 Proportions of responses of traditional and non-traditional fishers with low and high probabilities of encountering dolphins, who expressed perceptions that had positive themes

Theme, no of respondents	Proportion of responses within each fisher group (%) ^a			
	Trad		Non-trad	
	High	Low	High	Low
Dolphins helped fishers to catch fish, $n = 205^b$	75	83	64	63
Dolphins provided fishers with other economic benefits, $n = 32$	10	6	21	12
Dolphins benefited fishers (unspecified), $n = 26$	14	6	9	8
Dolphins were beautiful/gentle creatures, $n = 16$	0	3	6	13
Dolphins helped reduce other threats, $n = 3$	2	0	0	3
Dolphins protected/rescued fishers, $n = 2$	0	0	4	0

Trad traditional fisher, *non-trad* non-traditional fisher, *high* high probability of encountering dolphins, *low* low probability of encountering dolphins

^a Each respondent may have had more than one positive response

^b The total number of respondents who expressed each theme within a fisher group

DISCUSSION

Fisher Perceptions Towards Dolphins

The relationship between fishers and Irrawaddy dolphins at Chilika Lagoon is a clear example of the complexity of the perceptions of local people towards the wild species with which they share natural spaces. Fishers were overwhelmingly positively disposed towards dolphins, and their perceptions were strongly influenced by ecological, socioeconomic, and cultural drivers. An understanding of the complexity of human–wildlife interactions, and the drivers that influence them is usually not incorporated into standard conservation and management practices. A nuanced appreciation of the human–wildlife interface allows for a better understanding of how to proceed with wildlife conservation. For instance, at Chilika Lagoon, the human–wildlife relationship is complex, and influenced by multiple drivers, but is positive, currently undervalued, and worth further promoting. We suggest that investigating the drivers of human–wild species interactions could improve conservation outcomes, both in instances where local communities are positively disposed towards wild species, and in instances of human–wildlife conflict.

Drivers of Fisher Perceptions Towards Dolphins

Community background shapes worldviews and drives the attitudes and behavior of local people interacting with wild species and spaces. Villagers in China with more traditional practices were linked to more positive conservation attitudes in comparison with villages that used fewer traditional practices (Shen et al. 2012). The community identity of traditional fishers at Chilika is strongly associated with the lagoon and goes back several generations

(Pattanaik 2007). Thus, fisher group strongly influenced attitudes towards dolphins in responses to closed-ended questions. In particular, for traditional fishers who encountered dolphins regularly, the continued experience of fishing with dolphins reinforced culturally existing positive attitudes towards the animals.

Non-traditional fishers on the other hand, had changed their livelihood largely for economic reasons and were more neutral in their attitudes towards dolphins when compared to traditional fishers. However, they too showed positive perceptions towards dolphins in their open-ended responses, possibly due to the horizontal transfer of information from traditional to non-traditional fishers, and also possibly because of the other economic benefits that they derived from dolphins.

At Chilika Lagoon, observing dolphin foraging behavior at nets likely influenced fisher perceptions towards dolphins. Societies directly dependent on natural resources often construct a knowledge of causality with regard to natural phenomena and perceptions are often based on observations and the accumulation of abstract environmental information (Berkes et al. 2000; Berkes 2008). The capacity of stakeholders to accept sharing spaces with wild species, therefore, often reflects the perceived impacts (both positive and negative) of human–wildlife interactions on local communities (Carpenter et al. 2000). In our study, almost two-thirds of the fishers interviewed claimed that dolphins helped them fish and were able to recount detailed narratives to substantiate this belief.

Dolphins spent approximately half their foraging time barrier-foraging at stake nets. Given the high density of nets in the Outer Channel region, it is difficult to determine whether dolphins barrier-forage in this region due to the presence of stake nets, or because of the high density of preferred species coincidentally targeted by fishers.

Fig. 2 Barrier-foraging in Chilika Lagoon with **a** proportion of total foraging time in which Irrawaddy dolphins were observed employing various foraging strategies, **b** Irrawaddy dolphin barrier-foraging alongside a local fisher, **c** an illustration of how Irrawaddy dolphins herd fish towards stake nets during stake nets barrier-foraging, and **d** evidence of an Irrawaddy dolphin pushing fish against stake nets during barrier-foraging. All photos taken by Coralie D'Lima

However, during barrier-foraging, dolphins clearly used stake nets and exhibited a unique suite of behaviors as they herded fish from shallow channels towards stake nets against which they trapped the fish before eating them. Although barrier-foraging is not unique to Irrawaddy dolphins at Chilika Lagoon (Gazda et al. 2005), this specific adaptation of the Chilika dolphin population to fixed stake nets laid out by fishers suggests that dolphins benefit from

barrier-foraging in this location. Unlike gill nets, there is no risk of dolphins being entrapped in fixed stake nets, although the high density of stake nets could limit dolphin movement. Overall our results indicate that the presence of stake nets benefits the dolphins.

Taken together, our study indicates that fishers and dolphins in Chilika Lagoon share a mutually positive relationship; where fishers perceive dolphins to help them

Table 4 Results of the restricted maximum likelihood (REML) mixed model, showing the effect of dolphin presence (absent or present) as a fixed factor and year as a random factor on the (a) total CPUE, (b) CPUE of mullet, (c) CPUE of tiger prawn, (d) CPUE of prawns and shrimp, (e) CPUE of the remainder of the catch, and (f) catch income (per unit effort)

	Dependent variable	Transformation	df	F value	p value
(a)	Total CPUE of catch	Log	1, 80.73 ^a	1.49	0.23
(b)	CPUE of mullet	Square root	1, 79.82	11.37	0.00*
(c)	CPUE of tiger prawns	Square root	1, 80.09	0.24	0.63
(d)	CPUE of prawns and shrimp	Square root	1, 79.86	1.57	0.21
(e)	CPUE of remainder of catch	Log	1, 80.33	0.92	0.34
(f)	Catch income (per unit effort)	Square root	1, 77.85	11.94	0.00*

CPUE Catch per unit effort

* Significant effect at $p < 0.01$

^a Denominator degrees of freedom for approximate F tests may be in decimals and are calculated using algebraic derivatives ignoring fixed/boundary/singular variance parameters

catch fish and dolphins benefit by feeding at fisher nets. The Chilika fisher–dolphin interaction is different from other action-response forms of dolphin–fisher mutualisms that have been previously documented such as bottlenose dolphins (Orams 1997; Zappes et al. 2011) and Irrawaddy dolphins in Laos and Myanmar (Stacey and Hvenegaard 2002; Smith et al. 2009), that herd fish into nets. However, we argue that the Chilika fisher–dolphin interaction is comparable to other dolphin–fisher relationships and is equally important from the perspective of dolphin conservation.

At Chilika, other socioeconomic or cultural circumstances could have led fishers to blame dolphin barrier-foraging for a decline in their potential catch and livelihoods, leading to conflict. The sight of dolphins foraging could potentially have been interpreted by local fishers as provisioning or stealing. Instances of seals and otters foraging at fishing nets or from fish farms, for instance, have triggered significant conflict with fishers in other locations (Kemper et al. 2003; Freitas et al. 2007). Other positive drivers therefore likely influenced fisher perceptions towards dolphins.

Fish catch and income as well as local preferences were important drivers of fisher perceptions towards dolphins. Our observations indicate, however, that although catch volume or efficiency did not increase in the presence of dolphins, fisher incomes did show significant increases, linked to an increase in the catch of mullet (*Liza* sp., a locally preferred food fish species) when dolphins foraged at nets. The marked increase in the catch of mullet when dolphins forage at nets complements our behavioral observations of Irrawaddy dolphins feeding on mullet while barrier-foraging and is consistent with other reports of dolphins targeting shoaling species like mullet during dolphin–fisher cooperation (Orams 1997; Zappes et al. 2011). Although the bulk of the catch was formed by small, low value prawns and shrimp which influenced the CPUE

of the total catch, mullet is a preferred food fish species for local fishing communities because it has high economic value. Hence catches with mullet were higher in price on average in comparison to catches without mullet.

Although, fisher group, observing dolphin behavior, fish catch composition, and catch income partially explained positive fisher perceptions towards the Irrawaddy dolphin, culture and mythology also contributed to the overall positive attitudes of the fishers. As an example, in one mythic narrative, the Irrawaddy dolphin is cast as a symbolic and a practical helper of fishers, as well as an emissary of Goddess “Harchandi”, an embodiment of the Earth Mother and a powerful force in the local pantheon (Patel 1994). Similarly, culture and folklore drive local perceptions and utilization of the Amazon River dolphin (*Inia geoffrensis*) or boto, and also influence taboos against killing the animal, hence affecting its conservation status across the Amazon region (Gravena et al. 2008). Wild species are thus often connected to mythic traditions and narratives of local communities with which they share wild spaces, are an important part of local cultural identity (Passariello 1999; Telesco and Hall 2002), and should be used to benefit conservation wherever possible.

Conservation Implications of this Study for Irrawaddy Dolphins at Chilika Lagoon

Although fishers and dolphins in the Chilika lagoon appear to have a mutually positive interaction, conservation of the dolphins is a challenge in practice. The population of Irrawaddy dolphins at Chilika lagoon is likely “critically endangered” and decreasing (Sutaria and Marsh 2011). In addition, a small gill-net fishery occasionally operates in the lagoon, sometimes resulting in dolphin bycatch mortality. There is thus an urgent need to formulate management strategies if this population is to be conserved.

The current legal framework in India affords a limited and restrictive management toolbox for conserving endangered populations. The Indian Wildlife (Protection) Act, 1972 allows for the creation of National Parks and Sanctuaries, where little or no resource extraction is permitted (Anonymous 1992). If Chilika is made a National Park or Sanctuary, local fishing communities would not be able to participate in the design, implementation, or monitoring of the protected areas (Rajagopalan 2008). The creation of no-take zones and protected areas could have serious social costs due to the exclusion of local and traditional communities (Brockington et al. 2006) as it assumes that human–wildlife relationships are detrimental to the existence of wild species (Gómez-Pompa and Kaus 1992). Given the significant overlap between dolphins and fishers at Chilika, a protected area is thus likely to harm the existing positive fisher–dolphin interaction. Stakeholder acceptance of dolphins is likely to decrease (Carpenter et al. 2000) and the existing dolphin–fisher mutualism could turn to conflict.

An alternative would be to capitalize on the existing positive dolphin–fisher interaction in the formulation and implementation of Irrawaddy dolphin management strategies. These strategies need to be negotiated with local fishing communities in order to reach mutually acceptable solutions. Both traditional and non-traditional fishers need to be co-opted into management plans. In particular, traditional fisher beliefs should be used to build a constituency for Irrawaddy dolphin conservation. Existing policy for natural resource and wildlife management in India is still largely top-down (Rajagopalan 2008). However, management of the dolphin population at Chilika Lagoon requires the involvement and active engagement of local stakeholders and a change in management policy to a more pluralistic paradigm (Berkes 2007).

CONCLUSION

Conservation of threatened species in human-dominated landscapes needs to be based on an understanding of the multidimensional motivations and drivers that influence human–wildlife interactions. Amongst other factors, these drivers could be ecological, socioeconomic, or cultural. Particularly in developing countries, where human livelihoods overlap with the needs of wild species, protectionist conservation philosophy often results in considerable social costs to local people (Brockington et al. 2006). A purely preservationist approach may occasionally result in effective conservation of wildlife (Brooks et al. 2009) but is likely to harm the rapport between local and government stakeholders (West et al. 2006) as well as the existing relationships between animals and local communities

(Infield 2001), ultimately undermining conservation efforts. Teasing out the drivers of mutually positive human–threatened species interactions such as the fisher–dolphin interaction in the Chilika Lagoon is likely to provide scope for understanding how to improve management of the human–wildlife interface. Even in instances of negative human–wildlife interactions, which pose bigger challenges for wildlife conservation, a more refined understanding of human–wildlife relationships could crucially mitigate potential human–wildlife conflict.

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