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Composition of Large Prey Species of Irrawaddy Dolphins (*Orcaella brevirostris*) in the Mekong River: Implications for Conservation of the Prey Resources

Minmin Chen,[1] Liang Fang,[2] Xuequn Li,[3] Dara Saing,[4] Yuxi Lian,[1] Ping Zhang,[1] Kang Zhang,[1] and Daoping Yu[1]

[1]*Engineering Technology Research Center for Aquatic Organism Conservation and Water Ecosystem Restoration in University of Anhui Province, College of Life Science, Anqing Normal University, Anqing, China*
E-mail: ahyudp@126.com
[2]*South China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou, China*
[3]*Cambodian First Unite Construction Group, Phnom Penh, Cambodia*
[4]*Prek Leap National Institute of Agriculture, Phnom Penh, Cambodia*

Abstract

Information on the feeding habits of the critically endangered Irrawaddy dolphin (*Orcaella brevirostris*) in the Mekong River and how their diet overlaps with that of the species targeted by fisheries is limited. The information provided herein will be helpful for evaluating and protecting important dolphin food resources. The composition of large prey species of Irrawaddy dolphins and the extent of fish resources were surveyed in the Mekong River, Cambodia, using local ecological knowledge. The results showed that Irrawaddy dolphins fed on 13 species of large fish, with *Pangasius conchophilus*, *Cyclocheilichthys enoplos*, and *Hemibagrus wyckii* the most frequently consumed prey. Twelve of the 13 reported prey species were usually caught by fishers. The results also revealed that the average weight of fish caught daily by fishers was significantly lower in 2019 than about five years before that, regardless of the season. A significant decline in fish resources and a high overlap of dolphin diets with fishery target species indicate that Irrawaddy dolphins may also be threatened by prey depletion, especially during the dry season when dolphins are concentrated in deep pools.

Key Words: diet, feeding habits, fish resources, Irrawaddy dolphin, *Orcaella brevirostris*, Mekong River

Introduction

Anthropogenic impacts are the primary factors driving population declines among endangered or critically endangered freshwater cetaceans (Reeves et al., 2000; Braulik et al., 2014). Prey depletion due to overfishing and ecological deterioration is considered one of the main impacts (e.g., the Yangtze finless porpoise [*Neophocaena asiaeorientalis asiaeorientalis*], Wang, 2009; the Ganges river dolphin [*Platanista gangetica*], Chaudhary, 2007). Information on the feeding habits of dolphins helps evaluate required food resources and protection measures.

The Irrawaddy dolphin (*Orcaella brevirostris*), which inhabits river systems, has suffered a dramatic population decline, with an estimated population size of less than 400 individuals (Beasley et al., 2002; Kreb, 2004; Smith et al., 2004; Beasley, 2007; Limsong et al., 2017). All freshwater Irrawaddy dolphin populations have been classified as "Critically Endangered" in *The IUCN Red List* (International Union for Conservation of Nature [IUCN], 2013). The Irrawaddy dolphin population in the Mekong River is the largest freshwater population; however, this population of approximately 90 individuals is currently found only from the Kampi Pool (near Kratie) to Khone Falls within a range of < 200 km (Beasley, 2007; Ryan et al., 2011). The two most significant threats to this population are entanglement in fishing nets, especially gillnets, and destructive illegal fishing such as electrofishing (Baird & Mounsouphom, 1994, 1997; Beasley, 2007). However, prey depletion may also threaten this population because of the rapid decline in fish resources in the Mekong River (Beasley, 2007; Limsong et al., 2017).

Limited research has been performed on the feeding habits of freshwater Irrawaddy dolphin populations and how their diet overlaps with that of the species targeted by fisheries. Previous studies on feeding habits were based on qualitative descriptions or sporadic reports. For example, Baird & Mounsouphom (1994) described that dolphins in the Mekong River mainly feed on a

large number of small cyprinids such as *Cirrhinus* sp., *Lobocheilus melanotaenia*, and *Crossocheilus cf. reticulatus*. Stomach content analysis showed that catfish and carp, such as *Cirrhinus lobatus*, *Belodontichthys dinema*, silurid catfish, and pangasiid catfish, are consumed by dolphins (Marsh et al., 1989; Roberts & Baird, 1995; Baird & Mounsouphom, 1997). In addition to small fish, Irrawaddy dolphins also prey on large species. Previous studies have shown that the Irrawaddy dolphin feeds on the lower halves of larger fish, and the upper remains of nearly 20 species have been recorded across Mahakam, Ayeyawady, and Mekong (Baird & Mounsouphom, 1994, 1997; Win & Bu, 2019). This indicates that large fish are also a major source of food for the Irrawaddy dolphin, but this aspect of their diet has not been systematically investigated. Baird & Mounsouphom (1994) reported that villagers often found the upper halves of large fish floating in waters inhabited by Irrawaddy dolphins. This provides clues for studying the composition of large prey species of Irrawaddy dolphins in the Mekong River by utilizing local ecological knowledge (LEK).

LEK represents experiential knowledge from resource users derived from their interactions with the local environment (Inglis, 1993; Berkes et al., 2000; Newing, 2011). Questionnaire surveys to collect LEK from fishers are a potentially effective method for gathering and analyzing a wide range of information that is difficult to study or monitor, including the status of target species and ecological resources (Newing, 2011; Sousa et al., 2013; Ziembicki et al., 2013; Turvey et al., 2014; Marin et al., 2017), fishers' perceptions of dolphin–fishery interactions (Goetz et al., 2014; Gonzalvo et al., 2014), and patterns of bycatch in multiple cetacean species (Lopez et al., 2003; Liu et al., 2017).

Therefore, information on the large prey species targeted by Irrawaddy dolphins and relevant fish resources was collected for this study by conducting a questionnaire survey among the fishers. Fishery target species were also collected simultaneously to determine how the dolphins' diet overlaps with that of the fishery target species. The field survey was conducted along the Mekong River in the Kratie Province. The Kratie section of the Mekong River (~90 km) has the highest density of Irrawaddy dolphins, especially in deep pools from Kampi to Sambo (Beasley, 2007; Ryan et al., 2011). The objectives of this study were to identify the composition of large prey species of Irrawaddy dolphins in the Mekong River and to evaluate the status of prey resources. The results of this study will provide essential knowledge on the feeding habits of Irrawaddy dolphins and, thus, facilitate protection of key prey resources.

Methods

Study Area

A field survey was conducted along the Kratie section of the Mekong River in 2019. Four fishing communities (FCs) were chosen based on information from the Kratie Fishery Office (Figure 1). FC1, FC2, and FC3 were located along the river bank between Kampi and Sambo, and FC4 was located in the middle sandbar. Areas around FC2 through FC4 are the core zones of the Irrawaddy Dolphin Natural Reserve.

Field Survey

The panel administering the questionnaire comprised a cetacean researcher, a fishery researcher from the Prek Leap National Institute of Agriculture in Cambodia, a local fisheries official, and a Cambodian–Chinese translator. Not all families in the FCs were still fishing; therefore, we focused on homes where fishing nets were hanging outside.

LEK data were collected using a standard questionnaire, revised from conservation research on Chinese FCs by Turvey et al. (2010, 2014), that took approximately 20 min to complete. The questionnaire included a combination of multiple choice, short free response, and multipart questions. The aims of the survey and the time needed to complete it were conveyed to the respondents at the beginning of all interviews. They were also informed that the survey was voluntary and anonymous, that gender and ethnicity were not included, and that it was only used for scientific research. The respondents were only selected if they were residents and their main fishing area was the Mekong River. The respondents did not need to have fishing as their only type of work; however, fishing had to be their main work in both the dry and wet seasons. The questions were answered by one member from each family.

The respondents were first asked a series of questions about their age, fishing area, fishing gear, time spent fishing, whether the total amount of fish caught per year had changed from about 5 y prior to the survey, the average weight of fish caught daily during the dry (December to May) and wet (June to November) seasons about 5 y before 2019 (i.e., 2014), the average weight of fish caught daily during the dry and wet seasons in 2019, and the main fish species caught. They were then asked if they ever found any half-eaten fish around their fishing area. If yes, they were asked to describe the species and estimate how many kilograms the whole fish weighed, describe the predators, and explain why they thought that the half-eaten fish were preyed on by the predator they described. We showed respondents pictures

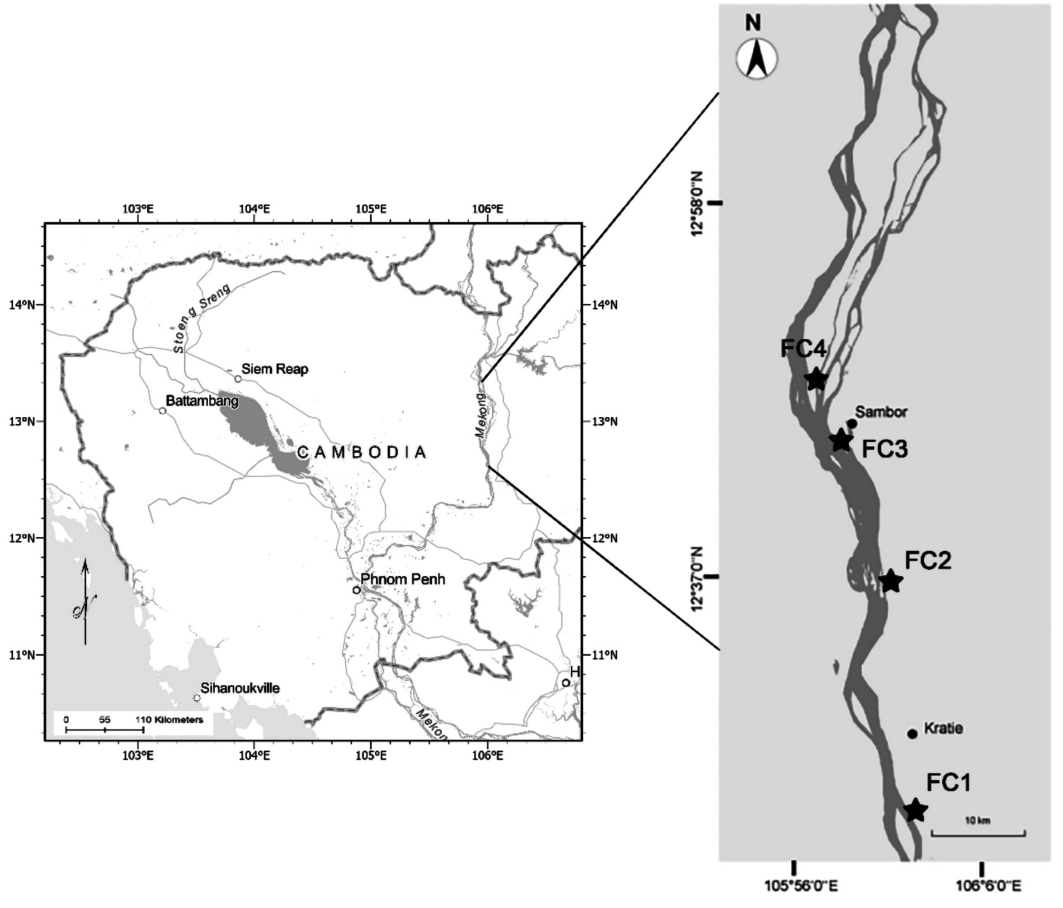

Figure 1. The Kratie section of the Mekong River. FC1 through FC4 indicate the four survey sites.

of fish in *Fishes of the Cambodian Mekong* (Rainboth, 1996) to confirm the half-eaten fish species.

Data Analysis

Fish species were identified by fishery researchers from the Prek Leap National Institute of Agriculture using *Fishes of the Cambodian Mekong* (Rainboth, 1996) and through references from the fishery office. The fish occurrence rate was defined as the number of respondents who mentioned the fish species divided by the total number of respondents. Fishers' fishing capacities and efforts differ; therefore, a paired-sample *t* test was used to compare the average weight of fish caught daily in the 5 y prior to the survey and in 2019. Statistical analyses were conducted using *SPSS*, Version 19.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Overview of Fisher Survey Data

A total of 53 effective questionnaires were collected. In total, 43.1% of the total respondents were 20 to 40 y old, 45.7% were 40 to 60 y old, and 11.2% were > 60 y old. The mean number of years that the respondents had been fishing was 22.1 ± 12.5 y. Five types of fishing gear were recorded: gillnets were mentioned by 88.2% of respondents; rolling hooks were mentioned by 68.6% of respondents; and traps, cast nets, and drag nets were mentioned by 33.3%, 11.8%, and 3.9% of respondents, respectively. Fishing was the only job for 10.3% of the respondents; while 89.7% of the respondents claimed that fishing was their main job.

Fish Species and Composition of Large Prey Species of Irrawaddy Dolphins

Eleven families and 36 fish species were caught, including 29 species in the dry season and 30 species in the wet season (Table 1). Fifteen species belonged to the Cyprinidae family (47.2%), followed by the Pangasiidae (16.7%), Siluridae (11.1%), and Bagridae (11.1%) families. During the dry season, *Pangasius conchophilus*, *Cirrhinus lobatus*, and *Cyclochecilichthys enoplos* exhibited higher occurrence rates. During the wet season, *Hemibagrus spilopterus*, *Pangasius conchophilus*, *Cirrhinus lobatus*, and *Hemibagrus wyckii* exhibited higher occurrence rates (Table 1).

Of the total respondents, 80.4% claimed that they had seen half-eaten fish that dolphins had preyed upon. The main reasons reported as to why they thought these fish were half-eaten by

Table 1. Fishery target species, composition of large prey species of the Irrawaddy dolphin (*Orcaella brevirostris*), and occurring rates. Asterisks (*) indicate large prey species of the Irrawaddy dolphin.

Fishery target species	Family of fish species	Occurring rates of fishery target species in the dry season (%)	Occurring rates of fishery target species in the wet season (%)	Occurring rates of dolphin prey species (%)
*Pangasius conchophilus**	Pangasiidae	39.7	15.5	18.5
*Cirrhinus lobatus**	Cyprinidae	22.4	15.5	1.5
*Cyclochcilichthys enoplos**	Cyprinidae	17.2	5.2	13.8
Thryssocypris tonlesapensis	Cyprinidae	13.8	5.2	--
Puntioplites proctozysron	Cyprinidae	13.8	12.1	--
*Cirrhinus microlepis**	Cyprinidae	12.1	1.7	6.2
*Hemibagrus spilopterus**	Bagridae	10.3	17.2	1.5
*Hemibagrus wyckii**	Bagridae	3.4	15.5	12.3
Chitala blanci	Notopteridae	8.6	3.4	--
Hypsibarbus pierrei	Cyprinidae	6.9	3.4	--
Helicophagus leptorhynchus	Pangasiidae	8.6	1.7	--
Channa striata	Channidae	3.4	5.2	--
Cyclocheilichthys repasson	Cyprinidae	5.2	3.4	--
*Kryptopterus apogon**	Siluridae	1.7	6.9	10.8
Osteochilus lini	Cyprinidae	5.2	1.7	--
Hemibagrus filamentus	Bagridae	3.4	6.9	--
Thynnichthys thynnoides	Cyprinidae	3.4	3.4	--
Clarias batrachus	Siluridae	0.0	5.2	--
Pangasius polyuranodon	Pangasiidae	3.4	1.7	--
Paralaubuca typus	Cyprinidae	1.7	3.4	--
Mystus nemurus	Bagridae	3.4	1.7	--
Wallago attu	Siluridae	0.0	3.4	--
Trichopodus microlepis	Percichthyidae	1.7	1.7	--
*Belodontichthys truncatus**	Siluridae	3.4	0.0	4.6
*Pangasius larnaudii**	Pangasiidae	1.7	1.7	6.2
Dangila spiolopleura	Cyprinidae	3.4	0.0	--
Mekongina erythrospila	Cyprinidae	1.7	1.7	--
Aulopareia janetae	Gobiidae	1.7	0.0	--
*Bagarius yarrelli**	Sisoridae	0.0	1.7	4.6
Puntius brevis	Cyprinidae	1.7	0.0	--
*Probarbus jullieni**	Cyprinidae	1.7	0.0	6.2
*Pangasius djambal**	Pangasiidae	0.0	1.7	10.8
Mastacembelus armatus	Mastacembelidae	0.0	1.7	--
Barbonymus gonionotus	Cyprinidae	0.0	1.7	--
Panagasius krempfi	Pangasiidae	0.0	1.7	--
Leptobarbus hoevenii	Cyprinidae	1.7	0.0	--
*Catlocarpio siamensis**	Cyprinidae	--	--	1.5

dolphins were as follows: (1) they saw dolphins preying on the large fish, and then the half-eaten fish floated up; (2) half-eaten fish often appeared in deep pools where the dolphins occurred frequently; (3) the bite marks indicated dolphins and not other carnivorous fish; (4) some fish were preyed on by dolphins but not by any other predators; and (5) other fishers all said that these types of fish were eaten by dolphins. The respondents further claimed that only the heads and upper bodies remained.

Thirteen half-eaten fish species were recorded in the 53 questionnaires (Table 1), of which Cyprinidae, Pangasiidae, Siluridae, Bagridae, and Sisoridae accounted for 38.4%, 23.1%, 15.4%, 15.4%, and 7.7%, respectively. All these prey species were included in the 36 fish species recorded as usually caught by fishers, except for *Catlocarpio siamensis*. According to the respondents' speculations, the total weight of the half-eaten fish ranged from 1 to 8 kg. The occurrence rates of *Pangasius conchophilus*, *Cyclocheilichthys enoplos*, *Hemibagrus wyckii*, *Kryptopterus apogon*, and *Pangasius djambal* were all > 10% (Table 1).

Fish Resources

Thirty-five effective questionnaires were collected to evaluate the average weight of fish caught daily during the dry and wet seasons in 2019 and about 5 y before that. The data showed that the average weight of fish caught daily in the dry and wet seasons in the earlier period (~2014) were 12.81 ± 9.83 kg and 13.89 ± 8.83 kg, respectively. In contrast, these weights were 4.10 ± 3.92 kg and 4.17 ± 3.91 kg, respectively, in 2019. The paired-sample *t* test revealed that the average weight of fish caught daily was significantly lower in 2019 than about 5 y previous, regardless of the season (dry season, $t(34) = 7.388$; $p < 0.001$; wet season, $t(34) = 8.546$; $p < 0.001$). In addition, 100% of the respondents claimed that fish resources have declined dramatically.

Discussion

Information on the composition of large prey species consumed by Irrawaddy dolphins in the Mekong River was successfully obtained using LEK. Of the total number of respondents, 80.4% claimed that they had seen half-eaten fish that were preyed upon by dolphins, and 13 species of large prey fish were recorded. *Pangasius conchophilus*, *Cyclocheilichthys enoplos*, *Hemibagrus wyckii*, *Kryptopterus apogon*, and *Pangasius djambal* all had occurrence rates higher than 10% and were presumed to be the main large prey species of Irrawaddy dolphins. *Kryptopterus apogon*, *Cyclocheilichthys enoplos*, and *Bagarius yarrelli*, recorded in this study, have also been previously reported by Baird & Mounsouphom (1994, 1997). Baird & Mounsouphom (1994) recorded a *Pangasius* sp. being preyed upon by Irrawaddy dolphins; however, it was not the same species identified in this study.

Irrawaddy dolphins have been reported to discard the heads and upper bodies of large fish, usually catfish, and feed only on the hind parts (Baird & Mounsouphom, 1994, 1997; Win & Bu, 2019). During our survey, the respondents also claimed that dolphins eat only the lower half of large fish. Of the five main large prey species of Irrawaddy dolphins identified in the present study, four were catfish. The hind part of the catfish is soft and palatable, and they are ideal prey species for Irrawaddy dolphins.

Depletion of prey can be catastrophic for animals. For example, prey depletion is the most important factor causing the Yangtze finless porpoise population to become critically endangered (Wang, 2009). Our results revealed a high overlap of dolphin diets with fishery target species. Fishers caught 36 fish species according to the survey. The large prey species of the Irrawaddy dolphin recorded in this study were all included among these 36 species, except for *Catlocarpio siamensis*. *Pangasius conchophilus* exhibited the highest occurrence rate of large prey species and also had the highest occurrence rate among the target fishery species (Table 1). *Cyclocheilichthys enoplos* and *Hemibagrus wyckii* were another two main large prey species, and both are important fishery target species. Of the fish species targeted by humans with occurrence rates higher than 10%, six were prey species of Irrawaddy dolphins. This may indicate a resource competition between dolphins and fisheries.

Our questionnaire included quantitative questions on the average weight of fish caught daily during the dry and wet seasons in 2019 and about 5 y before that. Although the LEK may provide biased quantitative estimates, particularly when relying on long-term recollection or comparisons, it can provide a general trend of changes in fish resources. The results showed that the average number of kilograms of fish caught daily was significantly lower in 2019 than around 2014, regardless of season. All respondents claimed that the fish resources of the Mekong River have shown a severe decline. The Kratie section of the Mekong River has the highest density of Irrawaddy dolphins in the entire river (Beasly, 2007; Ryan et al., 2011). A significant decline in fish resources and a high overlap of dolphin prey with fishery target species indicate that Irrawaddy dolphins may be threatened by prey depletion, especially in the dry season when dolphins are concentrated in a few deep pools.

In addition, our results revealed that gillnets and rolling hooks are the two main fishing gears widely used across the Kratie section, and more than half of the respondents claimed that electrofishing is a serious problem. Gillnets, rolling hooks, and electrofishing can cause direct injuries to small cetaceans (Reeves et al., 2003) and have been revealed as the primary factors causing the functional extinction of the Yangtze River dolphin (*Lipotes vexillifer*; Turvey et al., 2007). Similarly, these types of fishing gear can also increase the potential risk of accidental injury to Irrawaddy dolphins.

In conclusion, this study has shown that Irrawaddy dolphins in the Mekong River feed on 13 large fish species, mainly catfish, in addition to previously reported small fish (Marsh et al., 1989; Roberts & Baird, 1995; Baird & Mounsouphom, 1997). Irrawaddy dolphins are probably threatened by prey depletion based on the significant decline in fish resources and the high overlap of dolphin prey with fishery target species. The national government has already banned fishing in the core areas of the Irrawaddy Dolphin Natural Reserves. This strategy will largely ease the pressure on food resources and damage caused by fishing gear. We recommend monitoring dolphin food resources periodically, especially in deep-pool sections where dolphins are gathered during the dry season. This measure is critical for evaluating the status of food resources and providing timely food aid if needed.

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