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Diet Variation and Prey Composition of Exotic Clown Featherback, *Chitala ornata* (Gray 1831) (Osteoglossiformes: Notopteridae) in Laguna De Bay, Luzon Island, Philippines

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Abstract

Diet composition and gut fullness of introduced clown featherback, *Chitala ornata* (Gray 1831) were assessed from three sampling sites (west, central, and east regions) of Laguna de Bay (Philippines). A total of 203 specimens (10.18–98.5 cm) were collected through the fish trap, seining and gillnet fishing from January to March 2014. Twelve stomachs were empty and excluded from the study. From the 191 stomachs, eleven prey items were identified, with *Caridina* sp. being the most important prey item by number (83.3 %) and frequency of occurrence (54.4 %). Teleosts prey, particularly an endemic *Leiopotherapon plumbeus* (Kner 1864) was the most important food item by volume (41.6 %). Index of Preponderance and Index of Relative Importance recognised *Caridina* sp., and *L. plumbeus* as the two most important food items (in order of magnitude). Gut fullness was significantly different among geographical sites ($P < 0.01$), with populations from the central region having the highest prey diversity and teleost prey consumption. An ontogenetic dietary shift was observed, where small-sized *C. ornata* (≤ 45 cm) consumed mainly on crustaceans, whilst teleosts were the main prey type for larger *C. ornata* (> 46 cm). The proportional weight of teleost-based diet and diversity of food items increased with *C. ornata* length.

Keywords: endemic fish, feeding ecology, gut fullness, invasive species, preponderance

Introduction

Clown featherback *Chitala ornata* (Gray 1831) belongs to the “featherback family” (Notopteridae), which is characterised of having a long anal fin which is continuous with the caudal fin resulting to a peculiar laterally compressed knife-shaped body (Roberts 1992; Rainbowth 1996). It is silvery grey; lateral portion has 5–10 rows of ocellated spots at the base of the anal fin.The fish can grow up to 100 cm long (Kottelat 1998). It is naturally distributed in

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Cambodia, Laos, Thailand, and Vietnam and was introduced in other Southeast Asian countries (Froese and Pauly 2015). In the Philippines, the species is locally known as “arowana” and “knifefish”. It was introduced from Thailand with a permit from the Philippine Department of Agriculture and mainly intended as ornamental species for aquarium trade (Guerrero III 2014).

The *C. ornata* found their way in Laguna de Bay (Southern Luzon, Philippines) and is currently considered as the most problematic species in the lake (Punongbayan 2012; Guerrero III 2014). The *C. ornata* was reported to have predated in a number of cultured fishes and believed to be the major cause of abundance decline of various native species in the said lake. It was believed to have escaped from ornamental fish farms or intentionally released by fish hobbyists (LLDA 2012). It was assumed that it might be accidentally introduced into the lake after a flooding event caused by Typhoon Ketsana (Ondoy) in 2009 (Guerrero III 2014).

The predatory nature of *C. ornata* drives this study to investigate its invasion dynamics. One important biological parameter in invasion success is attributed to the organism’s efficient resource access and prey consumption (Garcia-Berthou 2007). As such, understanding the fish invasion mechanism solicits proper knowledge on its feeding ecology (Rosecchi et al. 2001; Raby et al. 2010). To date, there is still no comprehensive data available in scientific peer-reviewed literature concerning on feeding ecology of wild populations of *C. ornata* in invaded habitats within a shallow eutrophic lake. Hence, the objective of this study is to provide an assessment on diet composition, food indices, and gut fullness of *C. ornata*, with emphasis on spatial and size variation in diet.

Materials and Methods

Study sites

All samples of *C. ornata* were collected from Laguna de Bay (14° 21' N; 121° 13' E), the largest inland water body in the Philippines. The lake is located east of Metro Manila between the provinces of Laguna (southwest) and Rizal (northeast). In this region, dry months extend from December to May, whilst wet months are from June to November. It has a total area of 900 km^2, with a 285 km shoreline that delineates four bays. This shallow eutrophic lake has an average depth of 2 m. Salinity ranges from 0–5 ppt, and annual temperature varies from around 27–33 °C. The region has a dry (January to May) and wet (June to December) seasonal cycle. It is water-fed by the rivers and run-offs from highlands and nearby tributaries. Its long shoreline has numerous numbers of fish pens and cages (LLDA 2006). The sampling stations were Binangonan, Rizal for west region, Cardona, Rizal for the central region, and Santa Cruz, Laguna for the east region (Fig. 1).

West region is situated nearest to Metro Manila and in the industrial-urban area of Laguna and Rizal provinces. It is the most populated and developed among the watershed in Laguna de Bay. Commercial pen and cage culture, and artisanal fishing activities are largely concentrated in this region. The sampling site presented a substrate comprised mostly of mud and biodetritus (PEMSEA 2016). Central region is characterised by denuded hills and flat areas (Israel 2007), where the lake-side plain is being converted into crop and coconut plantation, and rural-residential areas. According to PEMSEA (2016), fish sanctuaries and open fishing were allocated in this lake's region. The sediments in the sampling stations are mostly sandy and clay-loam. East region almost rise steeply over flat terrain (Israel 2007), with highlands covered with secondary forest with varying height and deciduousness. It has the highest water quality score, with grade A in all water quality indicators (PEMSEA 2016). Substrates adjacent to the sampling stations have sandy to rocky bottom feature.

Fish collection

This study selected three sampling stations in every lake's region. Specimens of *C. ornata* were collected in the littoral zone in each sampling station during six periods from 11 January to 29 March 2014. Specimens were collected using a combination of 5 m bag seine net (1.2 mm mesh size) and 8 m drift gill nets (2 cm mesh size). The collection was carried-out during dawn to daylight hours (0500–1000 h). Both sampling gears were set in the vegetative littoral portions in each of the sampling stations where there are previous sightings of *C. ornata*. In one station in the west region, specimens were collected using fish traps made of bamboo pole and nets, which were used by Cuvin-Aralar (2014) for their lake biodiversity study. All fish specimens were submerged immediately on ice to prevent the stomach enzymes to continuously digest the food items and prevent the loss of resolution (Hyslop 1980). Prior to that, standard length (SL) of each specimen was measured to the nearest 0.01 cm.

Stomach content analyses

In the laboratory, the fish samples were incised from the anus up to the gills to expose the alimentary canal. The stomach was exenterated from the whole alimentary canal by separating the attached organs from it and cutting the stomach from the cardiac area to the pyloric section. An incision was performed in the lesser curvature of the stomach.The food contents of each *C. ornata* stomach were removed and transferred in gridded Petri dishes with tissue paper (no fixation). The sorted prey items were counted and identified to the lowest possible taxonomic level under a dissecting microscope. Unidentified prey items were excluded from the analysis. Wet weight of prey item was recorded to the nearest 0.01 g using an analytical balance. The volume of each prey taxa was measured by water displacement in a graduated cylinder.

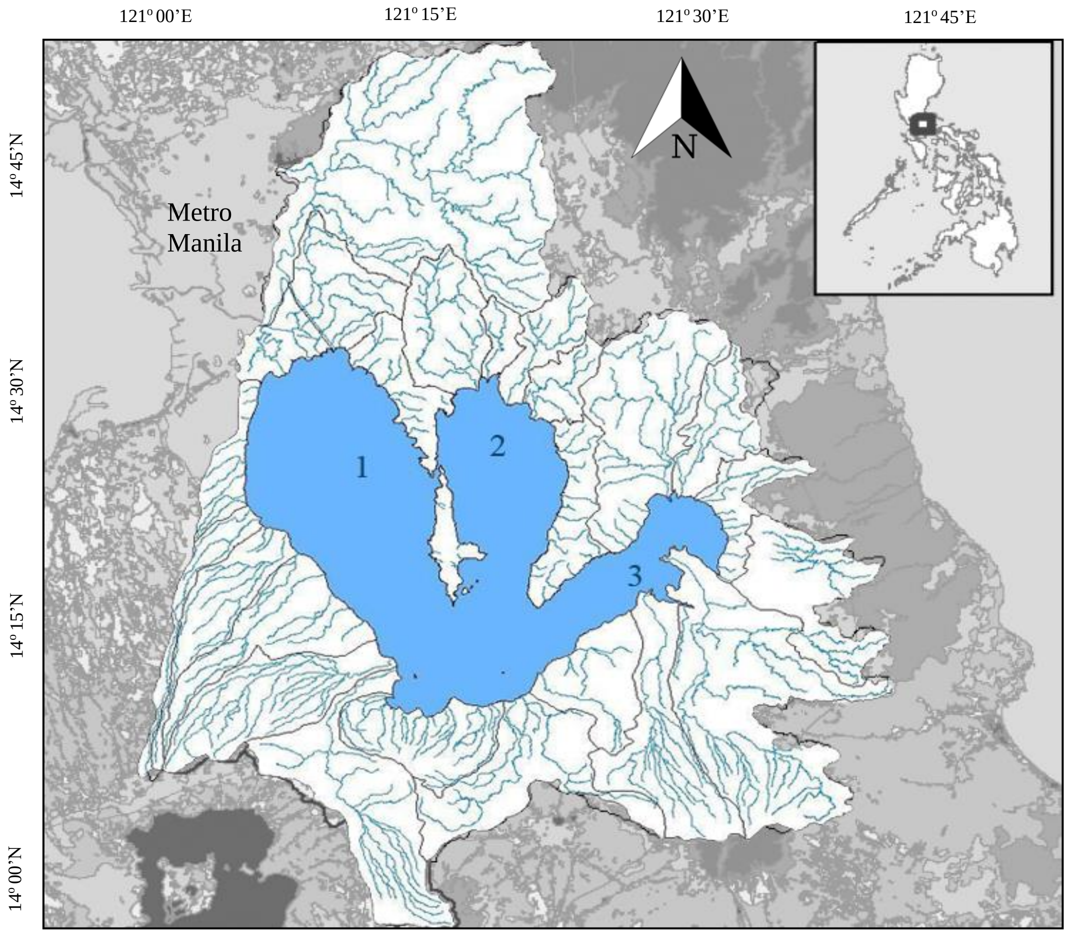

Fig. 1. Map of Laguna de Bay, Philippines showing the collection sites of *Chitala ornata*. West region (1), central region (2), and east region (3). Map modified from Israel (2007).

Data analyses

The relative measures of the prey quantity were evaluated by the following measures—frequency of occurrence (%F), percentage composition by number (%N), and percentage composition by volume (%V) (Hyslop 1980). Partial fullness index (PFI) (Bowering and Lilly 1992) was determined according to the equation: $\mathrm{PFI}_i = \frac{1}{n}\sum_{j=1}^{n}\frac{\mathrm{W}_{ij}}{\mathrm{L}_j^3}.10^4$ where Wij is the weight of prey i in fish j, Lj is the length of fish j and n is the number of fish in the sample. Partial fullness index was estimated to compare the weight of the prey found in stomachs in relation to predator size within and amongst sampling sites areas and size groups. Total fullness index (TFI) (Bowering and Lilly 1992) was calculated as follows: $\mathrm{TFI} = \sum_{i=1}^{m}\mathrm{PFI}$

where m is the number of prey categories.

Two indices of dietary importance were also calculated to evaluate the prey importance:

1. Index of preponderance (IOP) (Natarajan and Jhingran 1962): $\mathrm{IOP} = \frac{\%\mathrm{V}.\%\mathrm{F}}{\sum\%\mathrm{V}.\%\mathrm{F}}.100$
2. Index of relative importance (IRI) (Pinkas et al. 1971): $\mathrm{IRI} = \%\mathrm{F}\,(\%\mathrm{N} + \%\mathrm{V}); \%\mathrm{IRI} = (\mathrm{IRI}/\Sigma\mathrm{IRI}).100$

Prey item (taxon) diversity was computed using the Shannon-Weiner's Diversity Index. Prey dominance was determined using Simpson's Dominance Index. Spatial variation on prey composition, diversity and gut fullness were assessed among the samples collected from the three sampling sites. Samples of *C. ornata* were categorised in five size groups represented by successive SL intervals of 10 cm to evaluate the ontogenetic diet changes.

Non-parametric multivariate of analysis of variance (NPMANOVA) or PERMANOVA (Anderson 2001) was performed to differentiate the gut fullness of *C. ornata* populations among sampling sites, and size groups (P < 0.05). Prey item biomass and SL of *C. ornata* were transformed to $\log_{10}$ (x + 1) and the relationship were determined by nonlinear regression function: $y = ax^b$, where y = prey biomass, x = SL, and b = slope. Comparison of Shannon-Weiner diversity indices among the populations from the three sampling sites, and size groups were examined using diversity t-test as described by Magurran (1998) (P < 0.05). All statistical analyses were conducted using Paleontological Statistics Version 2.17 (Hammer et al. 2001) and SigmaPlot Version 10.

Results

Prey composition

The size of *C. ornata* specimens ranged from 10.18 to 98.5 cm SL with a mean SL (± SD) of 44.55 ± 16.36 cm (Table 1). No significant difference was found among the mean sizes of wild specimens from the three sampling sites (F = 2.53, P > 0.05). From a total of 203 stomachs examined, 191 contained foods (94 %), and twelve were empty. Eleven food categories were identified in the stomachs, including seven families of teleosts (Terapontidae, Cichlidae, Gobiidae, Cyprinidae, Ariidae, Synbranchidae, and Notopteridae), two families of crustaceans (Atyidae, and Palaemonidae), and three families of gastropods (Viviparidae, Pilidae, and Lymnaedae) (Table 2). Large prey items particularly, *Caridina* sp., a common lake prawn dominated the diet comprising 82.3 % by number (%N), 54.4 % by occurrence (%F). This was followed by an endemic silver therapon, *Leiopotherapon plumbeus* (Kner 1864) with 8.3 %N, and 16.7 %F. Endemic *L. plumbeus* was the most important food item by biomass (41.6 %V), and closely followed by *Caridina* sp. (36.5 %V). Overall, crustaceans comprised the diet of *C. ornata* at 86.4 % by number (N), 63.2 % by occurrence (F), and 39.4 % by volume (V). Teleost fish preys composed of 11.9 %N, 29.7 %F, and 61.6 %V in the diet, whilst gastropods represented at 1.7 %N, 7.15 %F, and 0.5 %V.

Food analysis indices

Prey item ranking based from IRI and IOP were presented in Table 2. The two most important food items that comprised 96.8 %IRI were *Caridina* sp., and *L. plumbeus* (in order of importance). In terms of %IOP, similar prey item order appeared with only minor variation in cumulative percentages (96.65 %IOP). Crustacean food items accounted to 86.6 %IRI and 73.2 %IOP, whilst summative %IRI and %IOP for teleosts (except *L. plumbeus*) accounted to 2.29 %, and 2.32 %, respectively.

Table 1. Sampling sites, sample sizes, and mean standard length of *Chitala ornata*.

Sampling sites	Mean SL ± SD (range, cm)	*n*	Empty stomachs, *n*
West region (Binangonan)	41.47 ± 16.74 (10.18–98.50)	82	7
Central region (Cardona)	48.03 ± 18.09 (10.88–87.80)	63	2
East region (Santa Cruz)	44.81 ± 14.59 (28.40–97.8)	58	3

Diet variation

The relationship between number, volume, and occurrence displayed a degree of diet variation among the *C. ornata* samples. *Caridina* sp. was recognised as the major prey item by number and exhibited the highest occurrence rate in the gut content. However, there were prey items including *L. plumbeus*, cichlids, *Hypophthalmichthys nobilis,* and *Arius* sp. that are important by biomass, but were found to have low occurrence rates. Gut fullness index was significantly varied among sites (PERMANOVA F = 5. 82; P < 0.001), with population from the central region being statistically higher from west and east region (P < 0.01). Fish samples from west and east sampling sites were statistically similar in terms of gut fullness (P = 0.313). Crustacean-based diet was dominant in the west region (83.18 %PFI) and east region (79.74 %PFI), but the crustacean consumption was lesser in the central region (56.15 %PFI). Proportions of teleost preys were 16.69 %PFI, and 20.01 %PFI from the west and east *C. ornata* populations, respectively, while fish samples from the central region had 43.74 % PFI. Gastropods consumption in all sites did not exceed 0.2 %PFI. It was observed that the proportion of crustacean prey items in the diet decreased, and the quantity of teleost preys in gut content increased with increasing SL of *C. ornata*. Biomass diet shift (i.e. from crustaceans to teleost) occurred at 46–55 cm SL class (Fig. 2). This ontogenetic diet variation was confirmed by PERMANOVA (F = 9.05, P < 0.001).

Table 2. Index of preponderance (IOP) and index of relative importance (IRI) of *Chitala ornata* (*n* = 191).

Prey items	Family	IOP	Rank	IRI	Rank
Crustacea					
Caridina sp.	Atyidae	71.85	1	85.73	1
Macrobrachium sp.	Palaemonidae	0.93	4.5	0.84	4
Teleostei					
Leiopotherapon plumbeus	Terapontidae	24.80	2	11.05	2
Cichlids	Cichlidae	0.93	4.5	1.08	3
Glossogobius sp.	Gobiidae	0.13	6.5	0.04	9
Hypophthalmichthys nobilis	Cyprinidae	0.04	8.5	0.20	7
Arius sp.	Ariidae	1.12	3	0.63	5
Monopterus albus	Synbranchidae	<0.01	11	<0.01	11
Chitala ornata	Notopteridae	0.04	8.5	0.01	10
Fish eggs	Unidentified	0.02	10	0.36	6
Gastropoda	-	0.13	6.5	0.06	8

Teleost food items were the principal stomach content of *C. ornata* with SL larger than 46 cm, whilst crustacean food items supplied the key food sources of smaller size category (< 45 cm SL) (Fig. 4). In terms of gut fullness, *C. ornata* at < 35 cm SL category was significantly comparable to 36–45 cm SL category ($P > 0.05$). The size mentioned above groups, however, were statistically different to bigger size categories (46–55, 56–65, and > 65 cm SL size groups) ($P \leq 0.008$). No significant variation was found in the pairwise comparison amongst the 46–55, 56–65, and > 65 cm SL size categories ($P \geq 0.07$). A significant exponential relationship was found between prey biomass and SL of *C. ornata* ($R^2 = 0.66$, $b = 5.24$, $P < 0.01$) (Fig. 3).

Taking cue from the preceding results, the overall dominance index was relatively high (0.73). The diversity of food items was highly affected by sampling locations. Central region had the highest diversity (*H'* = 0.94), and was significantly different from the west region (*H'* = 0.45, Diversity $t = -6.84$, $P < 0.01$), and east region (*H*' = 0.39, Diversity $t = 7.15$, $P < 0.01$). No significant variation was observed in the food item diversity between west and east region (Diversity $t = -0.84$, $P = 0.40$). In general, diversity index was about 0.66. For size class comparison, diversity of small size classes i.e. < 35 cm SL (*H'* = 0.33), and 35–45 cm SL (*H'* = 0.35) was statistically similar (Diversity $t = -0.29$, $P > 0.05$) and were significantly different to larger fish size categories, 46–55 cm SL (*H'* = 0.75), 56–65 cm SL (*H'* = 0.96), and > 65 cm SL (*H'* = 0.70) ($P < 0.01$). Highest diversity was observed in 56–65 cm SL, albeit this was not significantly different to 46–55 cm SL (Diversity $t = -1.11$, $P > 0.05$), and > 65 cm SL (Diversity $t = 1.31$, $P > 0.05$).

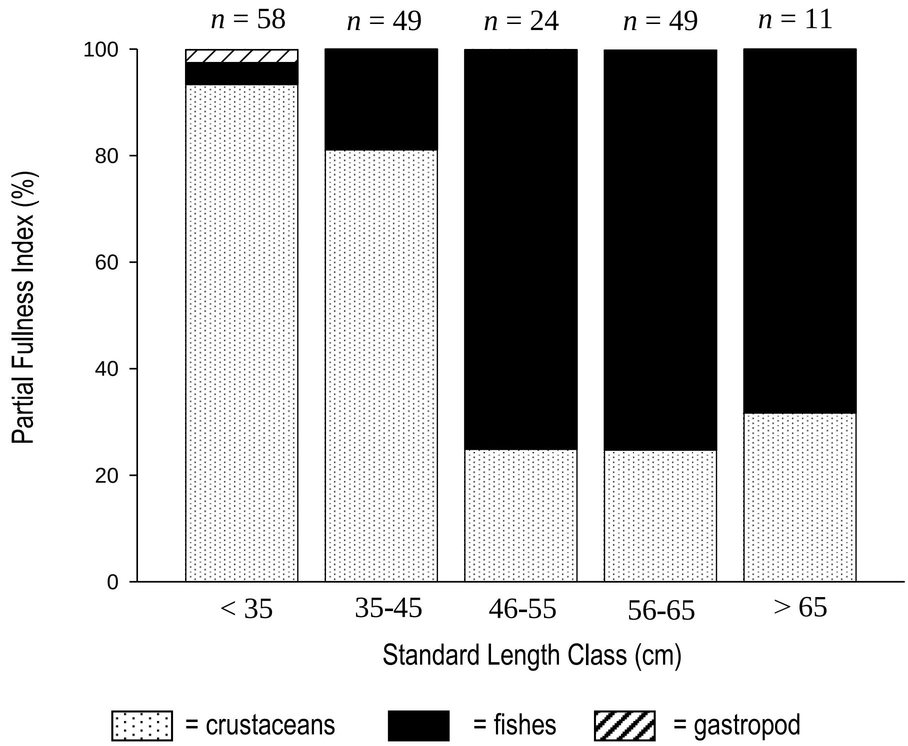

Fig. 2. Stack bar representation of main diet composition of *Chitala ornata* expressed as distribution of Partial Fullness Index amongst size groups.

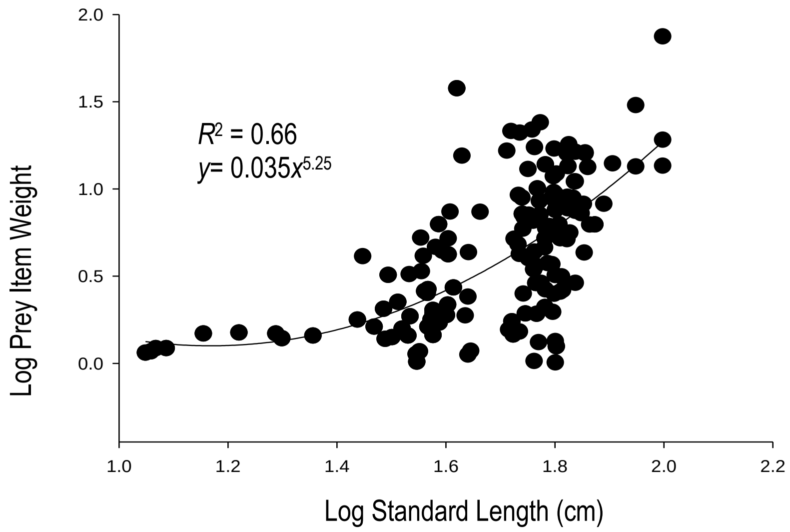

Fig. 3. Relationship of prey item biomass with standard length of *Chitala ornata*.

Discussion

The feeding habit of *C. ornata*, being a carnivorous fish species, reveals a high preference for preying crustaceans and teleost fishes. They exhibit a relatively wide feeding range and can be classified as a trophic generalist (Beauchamp et al. 1999). This kind of consumers has a diverse prey preference and a predator which spends little time foraging. Similar feeding ecology was also observed based from the samples collected from Mekong (Rainbowth 1996), and its conspecifics in Indian riverine system (Sarkar and Deepak 2009).

The euryphagic strategy and prey consumption pattern of *C. ornata* are linked to its invasion success in the lake. Recent reports and media anecdotes commented that *C. ornata* has a negative effect in aquaculture as the fish was observed to prey cultured fishes (e.g., milkfish and Nile tilapia) in fish pens and cages installed in the lake. Infestation of *C. ornata* initiates when small pelagic larvae of *C. ornata* pass through in cultured compartments (LLDA 2012; Mayuga 2016). In the present study, wild samples of *C. ornata* were found to have predated on and possibly competed for the available niche for the wide array of fish faunas in the lake. There was even a time that this feral species comprised 40 % of the major fish catch (by volume) in open water (Guerrero III 2014). It was also observed a number of specimens had consumed a juvenile form of its own kind signifying the cannibalistic behaviour of *C. ornata*.

Spatial variability on biomass and diversity of food items was observed, in which the central region seemed to be different from the east and west regions of the lake. The observed variability can be attributed to naturally different habitat types and fish distribution in the region, and not just by the size of the predator. The diversity of prey items in the diet also signifies the function of habitat availability in widening the diet spectrum of *C. ornata*. Crustaceans are distributed in the three lake regions, whereas fishes, specifically *L. plumbeus* are more concentrated in the central region than in west and east regions of the lake. As previously reported, the central region had the highest relative proportion of indigenous fish species by composition (PEMSEA 2016). Although it is not conclusive, the middle portion of the lake can be the breeding and foraging ground for *L. plumbeus* due to favourable water quality variables within that region.

The present study revealed size-dependent changes in their diet, in which the fish progressively shift from the crustacean-based diet into fish-based nourishment source, with substantial teleost predation commenced at SL of about 46 mm. From said class category, stomach capacity increased exponentially, and food items become more significantly diverse, with a higher preference for larger food items. This ontogenetic diet shift means to find food sources that will suffice the increased energy requirement during growth and reproduction (Werner and Gilliam 1984), and since the prey size can be correlated with energy value (Grossman et al. 1980), *C. ornata* tends to optimize energy intake through increased consumption of larger prey items at wider diversity. The trophic niche of *C. ornata* did not totally change but becomes more acute in consumption of new prey items or larger sizes of the same species. As the species becomes specialized on a specific resource or prey type, the fish may tend to be more efficient at foraging in that particular niche (Leonardos 2008).

The feeding behaviour exhibited by *C. ornata* may have a negative effect on the ecology of the lake by displacing other lacustrine species. It was alarming that an endemic *L. plumbeus* is one of the two most important preys, which is being favoured during the adult phase of *C. ornata*. Before this study, the natural populations of *L. plumbeus* in the lake have dwindled during the last several years (PSA 2017). Based on collated data from PSA (2017), after the total volume of the catch of *L. plumbeus* plummeted in 2009 (assumed year of introduction of *C. ornata*), the terapontid population has not been recovered since then (Fig. 4). With the presence of this highly predaceous fish species, *L. plumbeus* and other native taxa may become more prone to abundance decline and eventual displacement in the lake (Guerrero III 2014).

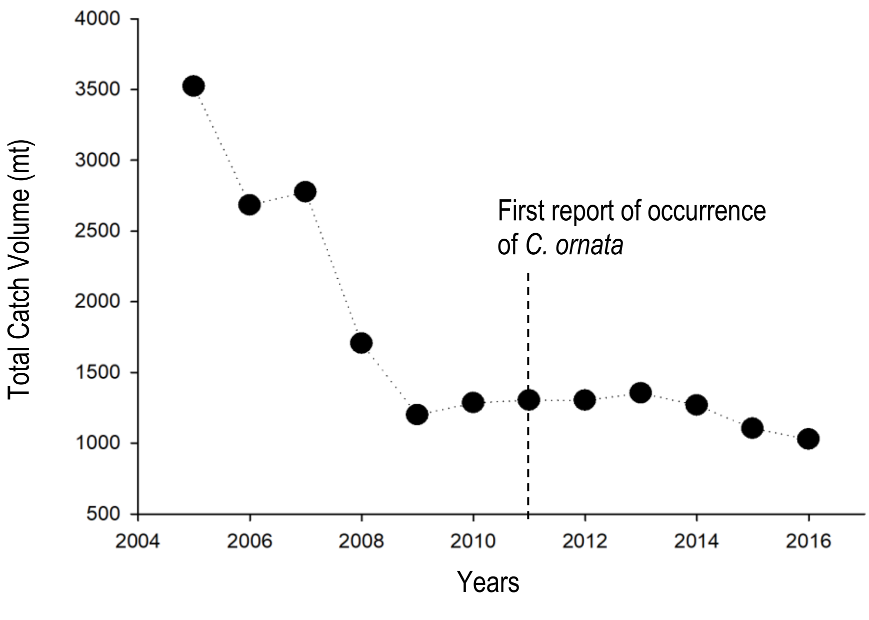

Fig. 4. Total catch volume (mt) of *Leiopotherapon plumbeus* in Laguna de Bay from 2005 to 2016 (PSA 2017).

A formal risk analysis shall be performed prior to the introduction of non-native fish species to evaluate their potential impact to the ecological integrity of inland waters. As stated in FAO 221, policies on illegal and unregulated introduction to include the biosecurity measures for aquatic cultured species shall be strictly implemented to prevent the escape of unwanted foreign aquatic species into different water bodies (DA-FAO 2003; Flores et al. 2015). It is also noteworthy to mention that there are initiatives including breeding and stock assessment programs (Aya et al. 2014; Añano et al. 2015; De Leon et al. 2017) and local-based education campaign (PEMSEA 2016) that are being implemented to restore the dwindling stock of *L. plumbeus*. Furthermore, the national government launched the "bounty system" and various value-adding endeavors for *C. ornata* to mitigate their populations in Laguna de Bay (Mayuga 2016).

Further investigation is suggested to assess the influence of sexes and seasonality on feeding pattern dynamics of *C. ornata*. Furthermore, the paucity of available data on prey assemblages present in the lake to correlate with the diet of *C. ornata* limits this study from further elucidating the prey selectivity of studied fish. An additional study can also be done towards the understanding the trophic interaction and spatio-temporal niche overlap between *C. ornata* and other fish species in aquatic sub-habitats in Laguna de Bay (e.g. aquaculture sites and riverine sections of the lake).

Conclusion

Stomach content analysis revealed the predatory nature of *C. ornata*, with native prawns, and an endemic silver therapon being the most important prey items in the diet. Although the diet shift and prey composition are affected by location and predator's size, it is clear that *C. ornata* is currently at the top of trophic echelon, that is, an apex predator among fish species in the lake, and its occurrence poses a new biological threat to the native fish assemblages within the lake. The present study provides baseline information on the feeding ecology of *C. ornata*, which is vital for the understanding of its invasion mechanism. Moreover, it is hoped that this study will be coordinated to local policymakers as a basis for improved conservation and management strategies of the lake ecology as well as the native fish species that are critically declining in numbers.

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