ROLE OF WADING BIRDS AS PREDATORS ON THE INVASIVE GOLDEN APPLE SNAIL (GAS) *POMACEA CANALICULATOR* IN WETLAND HABITATS OF MAUBIN DISTRICT, AYEYARWADY REGION

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Abstract

The present research of wading birds was observed in wetland habitats where intruded by invasive golden apple snail (GAS) *Pomacea canaliculator* in Maubin District, Ayeyarwady Region. Field surveys were carried out from February, 2019 to January, 2020. Distance sampling point count method (Buckland *et.al*., 2004) was applied in this research. A total of 21 wading bird species (2985 individuals) of 15 genera belonging to seven families in three orders were recorded. Out of total, 11 wading birds were observed as predatory or on the invasive species of golden apple snail. According to their food types, snails were main food type for them. These wading birds were molluscivores. The effects of the wading bird species on snail abundance were studied by the flock sizes of wading birds. The flock sizes of wading birds were recorded in two different sites (low wading birds pressure site and high wading birds pressure site). A total of 40 flocks were recorded in two different sites (25 flocks in low wading birds pressure site and 15 flocks in high wading birds pressure site). The highest numbers of flock size were recorded in the wading birds species of *Anastomus oscitans*, (11 flocks) and *Plegadis falcinellus* (5 flocks). During the study period, the golden apple snail destroyed the paddy fields only in a single night in the study site. Moreover, it consumed large quantities of different plant species which were as habitats for some bird species. The result showed the GAS has become a pest for pre-germinated rice crops and other aquatic plants in the study area. Based on the data, the wading birds could potentially feed on golden apple snails in their feeding ground. It is proposed that the wading birds were good predators or biological control agents on the invasive golden apple snail (GAS) *Pomacea canaliculator.*

Keywords: Golden apple snail (GAS), invasive, *Pomacea canaliculator*, wading birds, wetland

Introduction

Wading birds are most commonly associated with wetlands, streams, and other aquatic habitats. Most wading birds possess long legs and toes, and long and sometimes curved bills – adaptations enabling them to live and feed in shallow-water habitats. Wading birds rely heavily on wetland habitats including inland and coastal emergent marshes and wooded swamps. Wading birds are naturally adapted to wetlands, streams, and other aquatic ecosystems in North America. Habitats used by wading birds are diverse -ranging from aquatic complexes to dry upland meadows, pastures, and crop fields. Inland freshwater ponds, lakes, streams, wetlands with emergent aquatic vegetation, coastal marshes, riparian and wooded wetlands and bogs, mangroves, and estuaries are the most common sites used for feeding and nesting (Sauer *et.al*., 1999).

The freshwater golden apple snail (GAS), *Pomacea canaliculator* is endemic to South America. Golden apple snails were introduced several times in Asia (Hayes *et al*.,2008) as a food source and for use in commercial aquaculture, but these intended uses were not commercial successful. Thus, unused specimens of *P. canaliculator* were discarded into and rapidly spread through aquatic habitats (Halwart, 1994) and their release led to them becoming a major pest in wetland agricultural systems, most particularly as a rice pest (Hickel *et al*., 2012).). Invasive golden apple snails possess many characteristics of successful invaders. They exhibit high reproductive

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potential, fast growth rate, high dietary flexibility and strong resistance to a number of environmental conditions including hypoxia, high temperature and desiccation (Cowie, 2002; Estebenet and Martín, 2002; Boland *et al*., 2008). *Pomacea* (Ampullariidae) is a large genus of apple snails with more than 100 described species (Cowie and Thiengo, 2003). *Pomacea canaliculator* has become a major pest of rice in Asia and taro in Hawaii because of its voracious appetite for these semi-aquatic crops (Halwart, 1994; Naylor, 1996; Cowie, 2002; Joshi and Sebastian, 2006).

In Southeast Asia and elsewhere, chemical control of GAS using molluscicides has been favored due to the immediate results, but these chemicals are known to be detrimental to the environment and human health (Carlsson and Bronmark, 2006). Some farmers have attempted to remove or destroy the GAS egg masses deposited on vegetation as an alternative to chemical control (Joshi, 2007), whereas in South America wooden perches have been used to attract snail kites *Rosthramus sociabilis* as effective predators of the snails. In recent years, it has become clear that *P. canaliculata* could have reduced wetland biodiversity by grazing on macrophytes and by predation on benthic invertebrates, and altered wetland function by releasing nutrients into the water (Kolar and Lodge, 2001).

The role of wading bird species as predators on golden apple snail (GAS) *Pomacea canaliculator* in Ayeyarwady Region is still poorly known in the current situation. The systematically research has not been performed wading birds as predators on the invasive golden apple snail in this region. Hence, the present research was conducted to record the wading birds and their populations and flock size, to observe the food types of wading birds, to examine the role of the wading birds as predators on golden apple snails, to conduct the wading birds efficiency on snails abundance and to assess the threats by golden apple snail to wetland habitats.

Materials and Methods

Study area

Maubin District, Ayeyarwady Region lies at north latitude 16° 43' and east longitude 95° 39'. In Maubin District, there are four townships such as Maubin, Pantanaw, Nyaungdon, and Danuphyu. Ayeyarwady Region is situated in southern Myanmar (Figure 1).

Study site

Maubin Township

(North latitude 16° 41' and East longitude 95° 32')

Study period

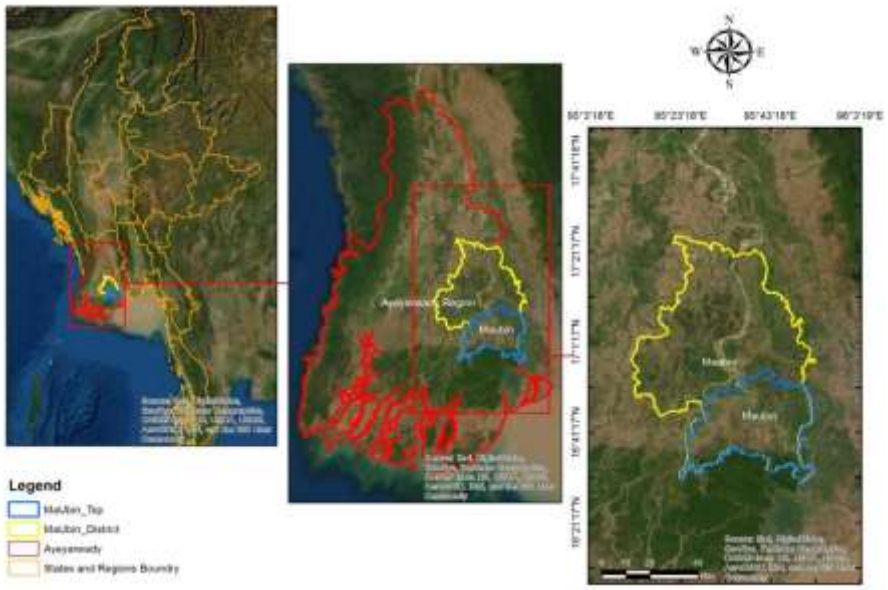
The survey was conducted from February, 2019 to January, 2020.

Field data collection

The research data were collected by the observing of the wading birds and their populations. Moreover, the distribution of golden apple snails (GAS), and varying sizes of empty shell of golden apple snail were also recorded (Plate 1). Distance sampling point transect method (Buckland *et al*., 2006) was applied for this research for recording the wading birds. Five to ten of transect lines were randomly established at study site. Transects length were between 500 m and 1000 m and at least 300 m apart each line according to the habitat types.

Data analysis

Recorded wading birds were identified by Lee *et al*., 2018 (A field guide to the Waterbirds of ASEAN). To determine the effect of the wading bird species on snails abundance by studying the flock sizes of wading birds and to assess the effect of the wading birds predation on snails varying sizes by randomly sampled live snails and preyed-on shell. The flock size of wading birds were recorded in two kinds of sites where visited by wading birds (1) low wading birds pressure sites (frequent but with low abundance, one flock = 1 – 50 individuals) (2) high wading birds pressure site (frequent and high abundance, one flock = 51+ individuals). The food types of wading birds were categorized by visual observation according to Lope *et.al*., 2003. No data collected by bird stomach content for categorize of bird food type. Snails were measured the size (height and width). The recorded snails categorized into 2 size-classes on their reproductive potential: (a) juvenile or non-reproductive (≤ 25mm heigh) and (b) adult or mature (> 25mm heigh) based on Carson *et.al*., 2004.



Source : Esri,Digital Globe, Geoeye, Earthstar Geographic,CNES/Airbus DS,USDA,USGS, AeroGRID, IGN, and the GIS user Community

Figure 1 Map of the study site

Results

Recorded wading birds in the wetland habitats

The survey was conducted in wetland habitats in Maubin Township, Maubin District, Ayeyarwady Region. During the survey period, a total of 21 wading birds species (2985 individuals) of 15 genera belonging to seven families in three orders were recorded in seven transect lines (Table 1). The highest numbers of species (16 species) were recorded in order Pelecaniformes and followed by order Charadriiformes (four species). The lowest number of species (one species) was recorded in order Gruiformes (Figure 2). Out of total, 11 wading birds were recorded as predators on the invasive species of golden apple snails. According to IUCN Red list, two near- threatened species of Black-headed Ibis *Threskiornis melanocephalus*) and Black-tailed Godwit *Limosa limosa* and one vulnerable species of Sarus Crane *Grus antigone* were observed in the study site during the research period (Plate 1).

Populations and flock size of wading birds

During the research period, 2985 individuals of wading birds were observed in the study site. The highest numbers of population were recorded in order Pelecaniformes (2689 individuals) and followed after by Gruiformes (210 individuals). The lowest numbers was recorded in order Charadriiformes (86 individuals) (Figure 3). The populations number of wading birds species of Asian Openbill (1825 individuals), Glossy Ibis (375 individuals) and Painted Stork (110 individuals) belonging to family Ciconidae and Threskiornithidae were recorded to be higher than other wading birds species. A total of 40 flocks were recorded in the study sites during the survey period. The highest numbers of flock were recorded in two wading birds species, such as Asian Openbill (11 flocks) and Glossy Ibis (5 flocks). The effects of the wading bird species on snail abundance were studied by flock size of wading birds. The flocks of wading birds were recorded in two kinds of sites (low wading birds pressure site and high wading birds pressure site). In low wading birds pressure site, 25 flocks of wading birds were recorded while 15 flocks were recorded in high wading birds pressure site. In low wading bird pressure site, the numbers of flock were higher but the population numbers of wading birds were lower. On the other hand, the population numbers of wading birds were higher but the flock numbers were lower in high wading birds pressure site (Table 2).

The role of the wading birds as predators on golden apple snail and their food types

In recorded 21 wading birds species, 11 wading birds were observed as predators on golden apple snail (GAS) (Plate 2). The food types of all wading birds were mollucs, crustaceans, crab, fish, insects, reptiles, amphibians, small mammals and aquatic plants by visual observation. Some wading birds were omnivores and they ate vegetable and animal matter. According to the results, five omnivores were recorded during the research period (Table 3). On the other hand, some wading birds ate fishes and which were main food for them. The main food types were different among wading bird species. In case of the diet types of wading birds, four folivores, three grainvores, 14 crustaceovores, 15 carnivores, 16 insectivores, 11 molluscivores, 13 picivores, and eight vermivores were recorded during the research period according to Lope *et.al*., 2003 (Figure 4). Out of total, five species of wading birds, such as Asian Openbill *Anastomus oscitans*, Glossy Ibis *Plegadis falcinellus*, Black- headed Ibis *Threskiornis melanocephalus* Painted Stork *Mycteria leucocephala* and Black- tailed godwit *Limosa limosa* were observed the higher eating rate on snails than other molluscivores because their main food type was snails. These wading birds searched for snails probed with their bills under and aquatic vegetation and rice stalks. The wading birds spent most of their foraging time in those snails' habitats. Mostly their feeding ground depending upon the presence or absence of the snails (GAS). All of molluscivores ate the adult snail's size than other size because it gave more profitability than small size snails.

The wading birds efficiency on golden apple snail (GAS) abundance

The golden apple snails were found throughout of the year in the study site and the abundance of GAS was more observed in pre and post raining season. The golden apple snail's egg masses were found mostly in the rainy season on the paddy plants and aquatic plants (Plate 2). In the cold season, the GAS burrows in the ground for hibernation. After rainy season, all paddy fields were burnt by landlord to grow the second crop and then there were shortly flooded afterwards by watering from irrigation canal where visited by wading birds. By the time, the wetlands habitats (paddy fields) allowed these snails to come out of their hibernating burrows grow and reproduce, and it was fascinating the wading birds as their feeding ground in those paddy fields. The wading birds, especially population abundance of molluscivores were totally depending upon snail abundance. In all observed of the wading birds, 11 species regarded as predators on golden apple snail. The wading birds of Asian Openbill *Anastomus oscitans*, Glossy

Ibis *Plegadis falcinellus*, Black- headed Ibis *Threskiornis melanocephalus* Painted Stork *Mycteria leucocephala* and Black- tailed Godwit *Limosa limosa* were observed to be higher the feeding rate than other wading birds species on golden apple snails (GAS). The highest numbers of population and flock size were recorded in Asian Openbill *Anastomus oscitans* (1825 individuals in 11 flocks) and follow by Glossy Ibis *Plegadis falcinellus* (375 individuals, in 5 flocks). These wading birds were recorded in two wading birds pressure sites (low and high wading birds pressure site). The population numbers of Asian Openbill were observed in higher in high wading birds pressure site than low wading birds pressure site. According to the data, the numbers of molluscivore bird species were recorded in lower but the individuals of bird were higher in each species. Based on the results, large flocks of wading birds could greatly reduce snail populations in their feeding ground in foraging time. Live snails and empty shells were observed in the wading birds' habitats after the foraging time.

Threats of golden apple snail (GAS) on wetland habitats

Wetland water, used for paddy field irrigation allows these snails to invade during irrigation and heavy rainfall events, and feed on sprouting rice seedlings resulting in extensive crop damage and other aquatic plants (Plate 2). The golden apple snail (GAS) destroyed the paddy fields only in a single night in some area. Moreover, it consumed large quantities of different plant species which depends by small wetland species for nesting, foraging and roosting in the study site. The loss of plants that used to provide income or habitat, this may led to high in water nutrient levels and algal blooms and, therefore, low water quality. At higher abundance, the snails have the capacity to completely eradicate most palatable plant species. Another important impact was the golden apple snail predation on other aquatic animals, mostly macroinvertebrates. Invasive aquatic invertebrates can have high negative environmental impacts. The results showed that golden apple snails were threat to this important wetland ecosystem.

Table 1 List of wading birds with their taxonomic status

Sr. no.	Scientific name	Common Name	Order	Family
1	*Anastomus oscitans*	Asian Openbill	Pelicaniformes	Ciconidae
2	*Mycteria leucocephala*	Painted Stork		Ciconidae
3	*Plegadis falcinellus*	Glossy Ibis		Threskiornithidae
4	*Threskiornis melanocephalus*	Black-headed Ibis		Threskiornithidae
5	*Nycticorax nycticorax*	Black-crowned Night-Heron		Ardeidae
6	*Ardeola grayii*	Indian Pond-Heron		Ardeidae
7	*Ardeola bacchus*	Chinese Pound-Heron		Ardeidae
8	*Ardea cinerea*	Grey Heron		Ardeidae
9	*Ardea purpurea*	Purple Heron		Ardeidae
10	*Bubulcus coromandus*	Eastern Cattle Egret		Ardeidae
11	*Ardea alba*	Great Egret		Ardeidae
12	*Mesophoyx intermedia*	Intermediate Egret		Ardeidae
13	*Egretta garzetta*	Little Egret		Ardeidae
14	*Ixobrychus sinesis*	Yellow Bittern		Ardeidae
15	*Ixobrychus cinnamomeus*	Cinnamon Bittern		Ardeidae
16	*Ixobrychus flavicollis*	Black Bittern		Ardeidae
17	*Grus antigone*	Sarus Crane	Gruiformes	Gruidae
18	*Vanellus cinereus*	Grey-headed Lapwing	Charadriiformes	Charadriidae
19	*Vanellus indicus*	Red -wattled Lapwing		Charadriidae
20	*Himantopus himantopus*	Black-winged Stilt		Recurvirostridae
21	*Limosa limosa*	Black -tailed Godwit		Scolopacidae

Table 2 Recorded number of wading birds and flock size in two wading birds pressure site

Sr. No.	Common Name	No. flock in low wading birds pressure site	No. flock in high wading birds pressure site	Total number of flock	Total number of individuals
1	Asian Openbill	3	8	11	1825
2	Painted Stork	1	1	2	110
3	Glossy Ibis	2	3	5	375
4	Black-headed Ibis	2		2	35
5	Black-crowned Night-Heron	1		1	47
6	Indian Pond-Heron	1		1	17
7	Chinese Pound-Heron	1		1	22
8	Grey Heron	1		1	14
9	Purple Heron	1		1	23
10	Eastern Cattle Egret	1	1	2	76
11	Great Egret	1		1	15
12	Intermediate Egret	1		1	33
13	Little Egret	1	1	2	68
14	Yellow Bittern	1		1	9
15	Cinnamon Bittern	1		1	13
16	Black Bittern	1		1	7
17	Sarus Crane	1	1	2	210
18	Grey-headed Lapwing	1		1	38
19	Red -wattled Lapwing	1		1	11
20	Black-winged Stilt	1		1	32
21	Black -tailed Godwit	1		1	5
	Total	**25**	**15**	**40**	**2985**

Table 3 List of recorded wading birds with their food types

Sr. no.	Common name	Vegetable matter		Animal matter						Omnivore	Food types
		Herbivore		Faunivore							
		FO	GR	CR	CA	IN	MO	PI	VE		
1	Asian Openbill			✓	✓		✓	✓	✓		mollusc, fishes, worms, reptiles amphibians, and
2	Glossy Ibis	✓		✓			✓		✓	✓	mollusc, crabs, worms and aquatic plants
3	Black-headed Ibis			✓			✓		✓		mollusc, insects, and worms
4	Painted Stork			✓	✓		✓	✓			mollusc, crustacean, fishes and crabs
5	Black-crowned Night-Heron	✓		✓	✓	✓		✓		✓	crustaceans, fishes, insects, reptiles, amphibian, and aquatic plants
6	Indian Pond-Heron			✓	✓	✓		✓			fishes, crustaceans, insects, and amphibians

Sr. no.	Common name	Vegetable matter		Animal matter						Omnivore	Food types
		Herbivore		Faunivore							
		FO	GR	CR	CA	IN	MO	PI	VE		
7	Chinese Pound-Heron			✓	✓			✓			fishes, crustaceans, insects, and amphibians
8	Grey Heron			✓	✓	✓		✓			fishes, crustaceans, insects, rodents and amphibians
9	Purple Heron			✓	✓	✓		✓			fishes, crustaceans, insects, rodents and amphibians
10	Eastern Cattle Egret				✓	✓			✓		insects, frogs, worms and reptiles
11	Great Egret			✓	✓	✓	✓	✓			fishes, frogs, crustaceans, mollucs and insects
12	Intermediate Egret			✓	✓	✓	✓	✓			fishes, frogs, crustaceans, mollucs and
13	Little Egret			✓	✓	✓	✓	✓	✓		frogs, fishes, crustaceans, insects and molluscs
14	Yellow Bittern				✓	✓		✓			fishes, insects and amphibians
15	Cinnamon Bittern				✓	✓		✓			fishes, insects and amphibians
16	Black Bittern				✓	✓		✓			fishes, insects and amphibians
17	Sarus Crane	✓	✓	✓	✓	✓	✓	✓		✓	crustaceans, molluscs, insects, fishes, reptiles, amphibians, seed, grain and aquatic plants
18	Grey-headed Lapwing		✓			✓	✓		✓	✓	insects, molluscs, worms, grains, and seed
19	Red -wattled Lapwing		✓			✓	✓		✓	✓	insects, molluscs, worms, grains, and seed
20	Black-winged Stilt			✓		✓					crustaceans and insects
21	Black -tailed Godwit	✓				✓	✓		✓		mollucs, insects, worms, amphibians and aquatic plants

Key

FO - Folivore IN - Insectivore MO - Molluscivore PI - Picivore

VE - Vermivore GR - Grainvore CR - Crustaceovore CA – Carnivore

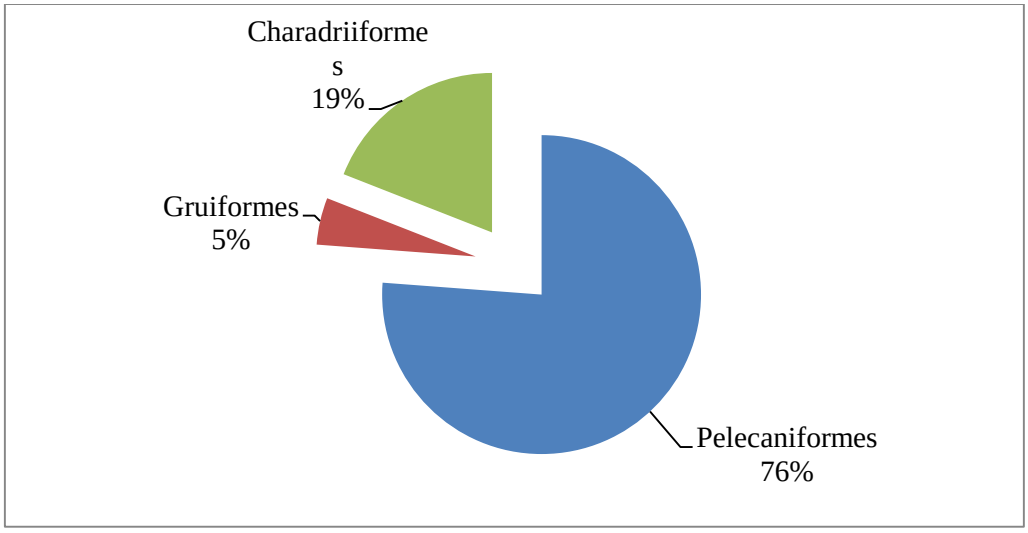


Figure 2 Recorded wading bird species percentage in order wise

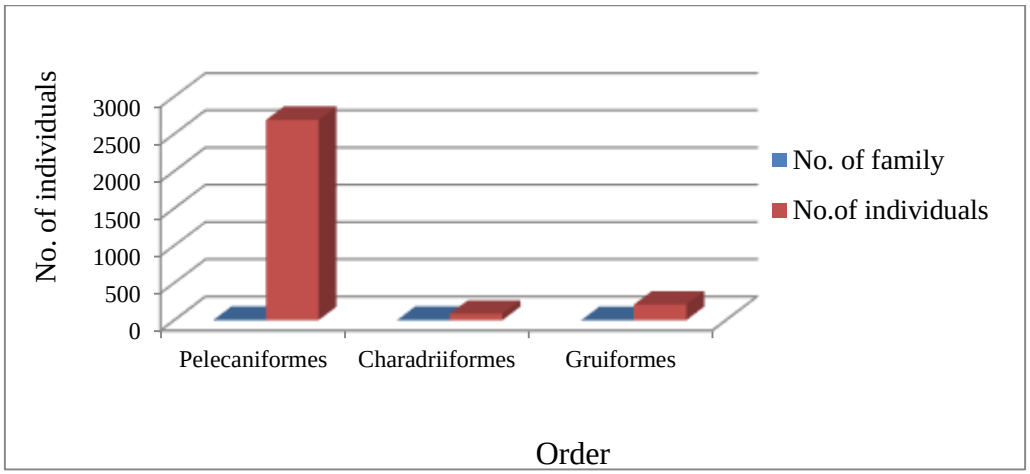


Figure 3 Recorded number of family and individuals of birds in different orders

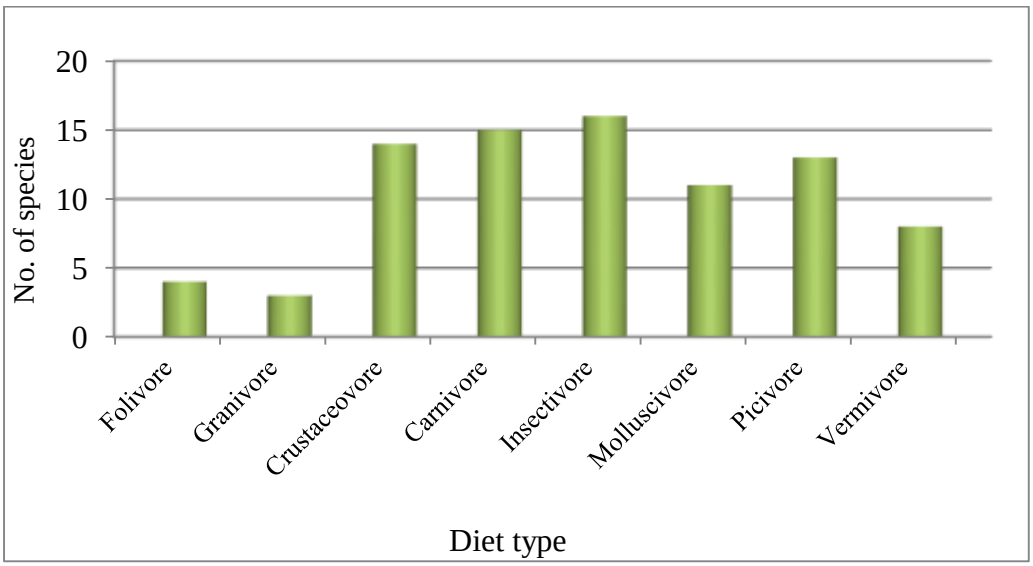


Figure 4 Recorded number of wading birds species with different diet types

A. *Anastomus oscitan*

B. *Plegadis falcinellus*

C. *Mycteria leucocephala*

D. *Threskiornis melanocephalus*

E. *Limosa limosa*

F. *Mesophoyx intermedia*

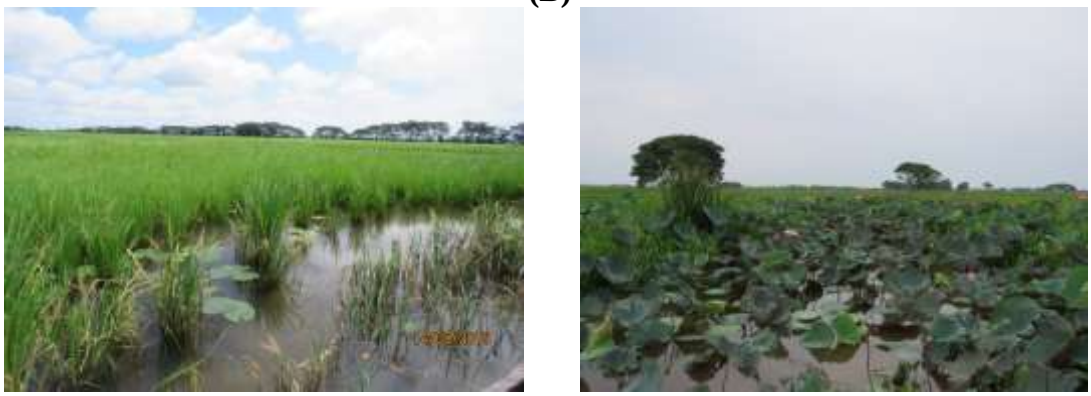
G. *Ardea purpurea*

H. *Grus antigone*

Plate 1 Recorded wading birds species in foraging ground

(A)

(B)



(C)

Plate 2 (A)Recorded photos of Golden apple snails and their empty shell

(B) Golden apple snails' egg masses on paddy plants and aquatic plants

(C) Golden apple snail damaged leaves of paddy plants and aquatic plants

Discussion

Wetlands are highly productive ecosystems that harbour great biodiversity and biological production that is important in the rural economy of many countries, especially in Southeast Asia (Carlsson *et al*., 2004). During the survey period, a total of 21 wading birds species of 15 genera belonging to seven families in three orders were recorded in seven transect lines of wetland habitats. The recorded wading birds' main food types were different among different species. Diet type categories were divided by their main food type. Based on the diet type category, 11 wading birds species were molluscivore and regarded as predators on the invasive golden apple snail (GAS). During the research period, 2985 individuals of wading birds were recorded in the wetland habitats. The highest population numbers were recorded in order Pelecaniformes (2689

individuals) and followed after by Gruiformes (210 individuals). The lowest numbers were recorded in order Charadriiformes (86 individuals). According to the data, the numbers of molluscivore bird species (11species) were recorded in lower but the individuals of bird were higher in each species. These wading bird species were recorded in all three orders. Their main food type was snail. The empty shell of snails left in the wetland habitats including paddy fields after the wading birds foraging. It may be assumed that the big flocks of wading birds could reduce the invasive snail population in their foraging ground.

Aquatic plants in freshwater systems provide substrate, refuge from predation, and a source of food for other aquatic organisms (Lodge *et al*., 1998). The invasion by the exotic golden apple snail *Pomacea canaliculata* in Southeast Asia is a threat to local agricultural economies as the snail consumes rice and naturally occurring aquatic plants (Halwart, 1994; Naylor, 1996). During the research period, the invasive gastropod of golden apple snails destroyed the paddy fields in a single night in some area. Likewise the aquatic plants were also eaten by golden apple snails. The results showed that golden apple snails were serious threat on wetland habitats. It was regarded as pests not only of rice but also of other aquatic plants of direct economic importance such as lotus, water hyacinth and water spinach. Aquatic plants in wetlands are thus an important part of rural everyday life in Southeast Asia, and many resident and transient organisms depend on wetland plants at some life stage (Mochida, 1991).

Most of the local farmers used molluscicide and hand picking for control the snails in the study site. Molluscicide used against invasive golden apple snail may also result in negative effects on organisms feeding on them. Current biological control with wading birds seems to be the promising option for sustainable GAS management. However, biocontrol must be added with other methods such as lowering water levels or draining the rice fields. Draining will not kill GAS because they are able to survive long periods of desiccation (Wada, 2004). By observing the field results, it may be assumed that, the wading birds especially molluscivores were predators on the invasive golden apple snail (GAS).

Conclusion

The invasion of the golden apple snail (GAS) *Pomacea canaliculator* and their destructive nature to the paddy land crop and wetland areas have become a major pest problem due to their growth and high reproductively, hence, causing drastic economic impact to the study site. The invasive GAS has become established and are numerous in various habitats, especially in paddy fields, this effects on people' livelihood. The results showed that the GAS has become a pest for pre-germinated rice crops and other aquatic plants in the study site. Most of the farmers prefer to choose chemical molluscicides which deliver fast and effective responses. However, the application has negative effect to the farmer's health and the ecosystem. Based on the data, the wading birds could potentially feed on the GAS. Therefore, a better and safer solution ought to be addressed. The research conducted for the wading birds as the most effective natural predators or biological control agents on the invasive golden apple snail (GAS) *Pomacea canaliculator.*

Acknowledgements

We are deeply indebted to Dr Aye Mi San Professor (Head), Zoology Department, University of Yangon who permitted to do this research. We would like to express our special thanks to landlords, Maubin Township for permission to do research in their rice fields. Special thanks are due to U Tin Aung Tun, freelance conservationist for his invaluable technical supporting during the survey period.

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