

LIFE HISTORY STUDIES AND HABITAT REQUIREMENTS OF THE APPLE SNAIL AT LAKE WOODRUFF NATIONAL WILDLIFE REFUGE

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ABSTRACT

The apple snail (*Pomacea paludosa*) is the exclusive food source of the Florida everglade kite (*Rostrhamus sociabilis plumbeus*), an endangered species. A study of the snail at Lake Woodruff National Wildlife Refuge was initiated during 1971 to gather information needed to manage the snail to insure a food supply for the kite.

Habitat studies revealed that apple snails are most abundant in alkaline waters containing an ample supply of submerged vegetation. A deficiency of dissolved oxygen may be a limiting factor in snail abundance.

It was found that individual female snails will produce many clusters of eggs during the year. Female snails may produce several clusters of fertile eggs from one mating but have to mate two or more times during the egg laying season to continue producing fertile eggs. The average hatching time for eggs kept under observation in the refuge office was 22 to 24 days. Under natural field conditions egg clusters kept under close observation hatched in 16 to 18 days.

INTRODUCTION

The Florida everglade kite (*Rostrhamus sociabilis plumbeus*) is one of the rarest birds in the United States. These birds once occurred throughout most of the Florida peninsula, but much of their former habitat has been destroyed by drainage. Approximately 1.4 million acres of freshwater marsh, about 37 percent of the original from the headwaters of the St. Johns River southward, have been eliminated by drainage (Harris 1972). Most of the remaining marsh is unsuitable for kite habitat. As a result of this habitat loss everglade kite numbers have diminished until at one point the estimated population was approximately 20 birds (Wachenfeld 1956). Census results from 1969 through 1972 range from 63 to 120 individuals with a yearly mean of 90 (Harris 1972).

The apple snail (*Pomacea paludosa*) is considered to be the sole food supply of the everglade kite (Cottam et al. 1939). Detailed studies of the habitat requirements of *Pomacea paludosa* have not been conducted, and there is a paucity of information concerning the life history of this snail (Perry 1971).

Lake Woodruff National Wildlife Refuge lies within the former range of the everglade kite. These birds have been observed on the refuge for brief periods on several occasions since the refuge was established in 1964. Apple snails are abundant on portions of the refuge, but present conditions of the wetlands within the refuge are apparently not suitable as kite feeding areas. It is believed by refuge personnel that suitable habitat could be provided by constructing a series of shallow impoundments which would meet the requirements of these birds. A prerequisite for such management is better knowledge of the life history and habitat requirements of the apple snail. A study of the snail was initiated on the refuge during 1971 to determine the needed information. This paper reports on some of the preliminary findings of the study.

METHODS

Habitat Requirements

A survey of snail egg clusters was made throughout the refuge by boat when the study was first initiated in 1971. It was discovered that the greatest concentration of snails present on the refuge was along Spring Garden Creek, and this area was selected for further study.

Three transects, 100 meters in length, were established in the creek at the head, middle, and mouth respectively. Each transect was placed in the emergent vegetation most distant from the shore to allow for easier access. Ten sample areas of one square meter each were randomly selected along each transect, and the number of unhatched egg clusters in each sample was recorded. Sampling was done twice during 1971 and four times during 1972. Freshly laid egg clusters were also counted during 1972.

Water samples were collected periodically from near each transect for chemical analyses. Sampling was done twice during 1971 and three times during 1972. Samples were analyzed at Stetson University, DeLand, Florida, with a Hach water analysis test kit during 1971. Analyses were done in the field during 1972 using a Hach kit. Water temperature was recorded at each station.

In addition to water tests on the refuge, an attempt was made to sample other areas within the range of the apple snail which have varying numbers of snails. It was theorized that by comparing such samples information might be gained as to why the differences in snail abundance occur.

Life History Studies

Two wire cages were constructed and placed in a small refuge impoundment in order to isolate individual snails for observation. Each cage was approximately two feet in diameter and was two feet high. The frame was constructed of wide mesh wire which was then covered with screen wire. A pair of snails captured while copulating was placed in one cage, while a female captured while in the process of egg laying was placed in the other cage. All snails were fed a diet of the most common submerged plants growing in the impoundment. The number of egg clusters produced, frequency of egg laying, mating habits, and food preferences were noted over a period of several months.

Ten freshly laid egg clusters were collected from Spring Garden Creek on 23 May 1972 and were placed in a sunny area in the refuge office. Daily observations were made to determine the average incubation period.

Thirty freshly laid egg clusters in a refuge impoundment were flagged with red ribbon on 14 August 1973. These clusters were closely observed to determine if the average incubation period under natural conditions differed from the result of the above test.

A small aquarium was set up in the refuge office and apple snails of varying sizes were kept under observation for various intervals of time. Food preferences and mating habits were noted.

RESULTS AND DISCUSSION

Habitat Requirements

The initial survey of snail egg clusters by boat indicated that snails are found throughout the refuge in all shoreline water areas (Perry 1971). Spring Garden Creek, which flows from Ponce DeLeon Spring to Lake Woodruff, contained greater concentrations of snails than other areas. This concentration appeared to be greatest at the head of the creek and progressively diminished in size at various distances down the creek.

The two initial counts of egg clusters along the three transects during 1971 gave further indication that there was a difference in snail abundance in the creek from the head to the mouth. A total of 117 unhatched egg clusters were counted during the two surveys at transect 1 located on the head of the creek; 84 at transect 2 in the middle of the creek; and 8 at transect 3 in the mouth. Surveys were conducted on 31 August 1971 and 1 October 1971 (Perry 1971).

During 1972 monthly surveys were made of the three transects from June through September. Freshly laid egg clusters were counted during these surveys as well as the total number of unhatched clusters. The reason for this was that it was feared that results obtained during 1971 might have been biased due to the nature of the emergent vegetation available for substrate at each transect. At transect 1 most of the available egg laying substrate consisted of vegetation that was rooted to the bottom of the creek. At transects 2 and 3 most of the available substrate for egg clusters consisted of floating mats of water hyacinths (*Eichhornia crassipes*). As a result of this it was thought highly probable that many more egg clusters might be available at transect 1 since the vegetation would not constantly be moving from one place to another. Since practically all egg laying is done at night and freshly laid egg clusters are easily detected for several hours the next morning, it was reasoned that they would give a better indication of the number of snails present in a given area than would the gross number of unhatched egg clusters.

These four surveys confirmed that snails were indeed more abundant near the head of the creek. The number of fresh egg clusters also appeared to be a better indicator of the number of snails present than did total unhatched egg clusters. The results of these surveys are shown in Table 1.

Initial water sampling done during 1971 indicated that the hydrogen ion concentration (pH) appeared significantly lower at transect 3 than at transects 1 and 2. Apparent color increased from transect 1 to 3. Both of these changes were anticipated. The spring water is clear and alkaline, but as the creek water proceeds further from Ponce DeLeon Spring drainage from the marshes surrounding the creek causes an increase of organic acids (Perry 1971).

Water sampling was conducted three times during the summer of 1972. Table 2 presents a summary of the data collected. There appears to be a significant decrease in total alkalinity as expressed in milligrams per liter (mg/l) calcium carbonate (CaCO₃) and in corresponding pH from the headwaters to the mouth of the creek. Total acidity increases from the headwaters to the mouth as would be expected since the creek is bordered by extensive swamps and marshes which drain into it. The average for dissolved oxygen at the mouth of the creek was only half of that at the headwaters. This can be explained by the fact that water hyacinth spraying causes large mats of dead hyacinths to drift into the mouth of the creek from upstream, and the decaying process uses up much of the available oxygen. During the water test conducted on this transect in July there was no available oxygen present, and a test for hydrogen sulfide showed 1 mg/l. At the time the area was covered with decaying water hyacinths.

Three additional sites were chosen in addition to refuge waters on which to conduct water sampling within the range of the apple snail. The first of these was nearby Silver Springs where snails are abundant. The run from Blue Springs to the St. Johns River was chosen because it is similar in appearance to Spring Garden Creek and because few or no snails are present. One sample was conducted in Okefenokee Swamp in southeast Georgia during a visit to the area. No snails are believed to be present in the swamp, although they can be found in nearby waters south of the swamp. Table 3 presents a comparison between the areas sampled.

Table 1. Results of egg cluster sampling during 1972, Spring Garden Creek, Lake Woodruff National Wildlife Refuge, Florida.

Date	Transect #1		Transect #2		Transect #3	
	Total # Clusters	# Fresh Clusters	Total # Clusters	# Fresh Clusters	Total # Clusters	# Fresh Clusters
27 June	38	4	25	5	11	1
27 July	57	2	10	2	23	0
30 August	29	5	17	2	8	0
14 September	26	3	4	0	6	0
Total	150	14	56	9	48	1

Table 2. Results of water analyses of Spring Garden Creek during 1972, Lake Woodruff National Wildlife Refuge, Florida.

Location & Date	Total Acidity (Mg/l CaCo ₃)	Total Alkalinity (Mg/l CaCo ₃)	CO ₂ (Mg/l)	Total Hardness (Mg/l CaCo ₃)	pH	Dissolved Oxygen (Mg/l)	Temp (°F)
Transect #1							
2 June	0	120	5	222	8.7	7	79
3 July	23	154	20	257	8.3	7	84
12 Sept.	23	137	20	205	7.3	5	80
Mean	15	137	15	228	8.1	6	81
Transect #2							
2 June	17	137	15	222	7.2	4	78
3 July	34	137	30	256	8.0	6	86
12 Sept.	29	68	25	137	6.5	4	79
Mean	27	114	23	205	7.2	5	81
Transect #3							
2 June	29	103	25	256	6.8	2	76
3 July	46	120	40	222	6.6	0*	84
12 Sept.	17	68	15	188	7.4	4	80
Mean	31	97	27	333	6.9	3	80

*A test for hydrogen sulfide showed 1 Mg/l.

Table 3. Results of water analyses of various areas within the range of the apple snail (*Pomacea patudosa*) during 1972.

Location	Total Acidity (Mg/l CaCo3)	Total Alkalinity (Mg/l CaCo3)	CO2 (Mg/l)	Total Hardness (Mg/l CaCo3)	pH	Dissolved Oxygen (Mg/l)	Temp. (°F)
Silver Springs Run (1 analysis)	17	171	10	188	8.5	4	74
Spring Garden Creek (3 analyses)	15	137	15	228	8.1	6	81
Transect #1	27	114	23	205	7.2	5	81
Transect #2	31	97	27	333	6.9	3	80
Transect #3	57	154	50	325	8.0	2	74
Blue Springs Run (1 analysis)	29	0	25	17	4.5	-	78
Okefenokee Swamp (1 analysis)							

The one water characteristic which appears to have the best chance of influencing snail abundance in the waters sampled is total alkalinity as expressed in mg/l calcium carbonate (CaCO₃). This is also reflected in pH readings which are directly related to the degree of alkalinity or acidity. In all areas sampled that have heavy concentrations of snails relatively high alkalinity and pH readings were recorded.

Alkaline waters are no guarantee of snail abundance, however, as witnessed by Blue Springs Run. The water sample taken here showed a high alkaline content, but few or no snails are present in the area. Dissolved oxygen was low in the run and could account for the lack of snails, but the most likely reason is a general lack of submerged vegetation. The water is extremely clear, and a sand bottom can be seen throughout most of the run. Lack of vegetation could also account for the lack of dissolved oxygen, since there are no plants available to release oxygen into the water.

There is a possibility that lack of dissolved oxygen could have an effect on very young snails, and this may be a contributing factor as to why snails are scarce at the mouth of Spring Garden Creek. Observation of young snails in an aquarium by the author has shown that they are extremely reluctant to leave the water unless they are under some type of stress. Most of the young snails that did leave the water were later found dead on the sides of the aquarium. It is possible that a lack of oxygen in the water could create a stress condition causing the young snails to leave the water and perish.

Based upon the results of these surveys it is theorized that the limiting factors on apple snails within their range are probably alkalinity, which reflects the amount of calcium carbonate present, submerged aquatics necessary for food and cover, and possibly dissolved oxygen. This closely correlates with the findings of Pennak (1953) who stated that calcium carbonate is the essential material for shell construction in snails. He contended that this is the reason that hard water contains many snail species and many individuals, while soft water contains few. Pennak stated that water areas low in carbonates are usually acidic, and therefore more snail species and individuals occur under alkaline conditions. He also stated that dissolved oxygen is important for snails and is the reason that snail species and individuals are few and depauperate in water greater than 3 meters where dissolved oxygen is reduced.

Life History Studies

Mating. One possible method of introducing snails into a newly developed area would be by transplanting them from another area. It was found that the easiest way to obtain a fairly large number of snails on this refuge was to collect them at night when they emerge from the water. Most of the snails collected in this manner were believed to be females in the process of egg laying. If this is true it would be desirable to know how frequently mating is necessary in order for the females to continue producing fertile eggs.

Two wire cages were constructed and placed in one of the refuge impoundments. On 16 March 1972 a female snail captured while in the process of egg laying was placed in cage number 1, and a pair of snails caught while copulating was placed in cage number 2. Another pair of snails was later placed in an aquarium in the refuge office in order to observe their actions. All snails were furnished an abundant food supply and substrate for egg laying.

The snails placed in the aquarium were observed mating frequently. This may have been due to their close proximity to each other in the aquarium and does not necessarily reflect their behavior under natural conditions. On two occasions the pair of snails in cage number 2 were also observed copulating when the cage was removed for inspection.

The females placed in the wire cages produced many egg clusters during the year. The isolated female in cage number 1 produced a total of 25 egg clusters

while the mated female in cage number 2 produced a total of 21 egg clusters. This is discussed further under egg production.

The isolated female produced a minimum of 10 fertile egg clusters before the first infertile eggs were laid. She produced 4 infertile clusters and was then placed in an aquarium with a male. After mating she was again placed in the cage and again started producing fertile eggs. Due to the possible damage of the last few egg clusters by prolonged flooding it was impossible to determine if all remaining egg clusters produced were fertile. All eggs produced by the snail in cage number 2 were fertile.

This study indicates that female apple snails can produce fertile eggs for a considerable time after mating. It does not appear necessary to have an equal ratio between sexes in order to produce the maximum number of fertile eggs.

Since at the present time it is not known what percent of the snail population is composed of egg producing females, it would appear that the quickest and best results from transplanting could be achieved by concentrating on collecting egg laying females provided that a lesser number of male snails could be provided by some other means. This could be done by random collection with a net or some other capture device.

Egg Production. It is desirable to know the number of egg clusters produced by a female snail during a year for a variety of reasons. Among these are such information would be useful in determining the number of females necessary for a successful transplant program and would also serve as a possible key to snail abundance within an area.

The number of egg clusters produced by the two caged female snails were recorded throughout the summer. An effort was made to determine the exact laying date, but this was not always possible due to high water levels, vacations, etc. General field observations were made to determine the earliest laying date under natural conditions.

The first observation of snail eggs for 1972 was on 2 March when three clusters approximately one day old were observed on a boat house near Ponce DeLeon Spring. Most of the early egg laying appeared to occur near the spring and may indicate the effect of water temperature on stimulating egg production.

The two females kept under observation during the summer were placed in their respective cages on 16 March 1972. The snail in cage number 1 produced a minimum of 25 egg clusters during the year. Her first eggs were laid on 18 March and her last on 8 September. The snail in cage number 2 produced a minimum of 21 egg clusters. Her first eggs were laid on 22 March and the last cluster was laid on 24 July. Usually three to four days would elapse between egg laying. Both female snails were found dead shortly after the last clusters of eggs were produced. The cause of death is unknown. Table 4 presents a breakdown of egg production by dates.

Incubation. Little information is available on the length of the incubation period for apple snail eggs. Casual observation by a number of individuals have placed this at between 15 to 20 days. An effort was made to try to refine this to a more specific period.

Ten freshly laid egg clusters were collected on 23 May 1972 and placed in a sunny area in the refuge office. Daily observations were made to determine hatching dates. The first eggs hatched 21 days after laying, and all the eggs that hatched had done so within 25 days. The average incubation period for the ten clusters was 22 to 24 days.

The first hatching among thirty egg clusters that were kept under observation in a refuge impoundment during August, 1973 occurred sixteen days after they were laid. All clusters had hatched by the end of the eighteenth day. This was a significantly shorter incubation period than was experienced for the egg clusters hatched in the refuge office. It is theorized that temperature and the amount of sunlight are probably the major factors influencing the length of incubation.

Table 4. Frequency of egg laying by two captive apple snails (*Pomacea paludosa*) during 1972, Lake Woodruff National Wildlife Refuge.

Egg Cluster #	Date Laid	
	Snail #1	Snail #2
1	18 Mar.	22 Mar.
2	20 Mar.	14 Apr.
3	24 Mar.	15 Apr.
4	28 Mar.	Between 20 Apr. - 1 May
(5	Between 28 Mar.	5 May
6	and	9 May
7)	11 Apr.	15 May
8	13 Apr.	19 May
9	17 Apr.	1 June
10	Between 10 Apr. - 1 May	6 June
11	5 May	13 June
12	10 May	17 June
13	15 May	20 June
14	18 May	26 June
15	8 July	29 June
16	11 July	4 July
17	12 July	13 July
18	15 July	16 July
19	17 July	20 July
20	19 July	21 July
21	22 July	24 July
22	29 July	
23	18 Aug.	
24	31 Aug.	
25	8 Sept.	

Food Habits. If a snail management system utilizing impoundments is to succeed, it is important to know if snails will feed upon the primary submerged aquatics which can be produced in such impoundments. This study was set up to determine if snails could survive on the abundant muskgrass (*Chara sp.*) and spiny naiad (*Naias marina*) available in managed impoundments on the refuge. An ample supply of these two plants was kept available at all times to the snails that were held in cages. They fed readily on both plants and appeared to do well. Some mortality was observed among young snails, but this was believed due to factors other than the food supply. These two plants appear to be an adequate food supply for snails in managed impoundments.

CONCLUSIONS

This study has placed major emphasis on determining habitat requirements and the life history of the apple snail on Lake Woodruff National Wildlife Refuge. Some of the data derived to date has provided information not previously known. Other information gained is not completely substantiated

and may only indicate possible trends. Preliminary findings from this study are as follows:

(1) Apple snails are most abundant in alkaline waters containing an ample supply of submerged vegetation. A lack of dissolved oxygen may cause a decrease in snail abundance.

(2) Female apple snails may produce a number of fertile egg clusters from only one mating.

(3) Female apple snails can produce many egg clusters during the egg laying season.

(4) The average incubation period for eggs tested in the refuge office was 22 to 24 days. Eggs under natural conditions in a refuge impoundment hatched in 16 to 18 days.

(5) Apple snails appear to thrive upon muskgrass (*Chara sp.*) and spiny naiad (*Naias marina*), two of the most common submerged aquatics produced in impoundments at Lake Woodruff National Wildlife Refuge.

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