CHAPTER 11. BENTHIC MACROINVERTEBRATES, APPENDIX 11.F LITERATURE REVIEW OF HYDROLOGIC REQUIREMENTS OF CRAYFISH AND APPLE SNAIL IN THE ST. JOHNS RIVER

by

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2011

APPENDIX 11.F

REVIEW OF THE LITERATURE ON HYDROLOGIC REQUIREMENTS OF CRAYFISH AND APPLE SNAIL

Crayfish. Crayfish were selected as a target taxon of freshwater benthic macroinvertebrate due to their importance in aquatic food webs as consumers of plant material and important prey items for many vertebrates of "human interest." These include sport fish (largemouth bass and *Lepomis* spp.), birds of conservation interest (wading birds such as Glossy and White ibis, Wood stork, and various herons and egrets), and herpetofauna (pig frog, striped swamp snake). Crayfish are particularly important members of the benthic fauna (in terms of abundance and biomass) in marsh areas of the upper St. Johns Basin (headwaters to Puzzle Lake) and probably the floodplain marsh areas of the middle basin between Lakes Harney and Monroe. Crayfish are also important from an overall conservation perspective, in that they are one of the more imperiled groups of freshwater fauna. Nationwide, 51% of crayfish taxa are considered imperiled or vulnerable to extinction (Master et al. 1998)

The two main taxa of crayfish found in the southern half of the St. Johns River basin are *Procambarus alleni* and *Procambarus fallax* (Franz and Franz 1990; Hobbs 1942). *P. alleni* is endemic to Florida (Franz and Franz 1990; Hobbs 1942). Franz and Franz (1990) indicate that *P. fallax* is also endemic to the state, although Hobbs (1942) reports collections from southern Georgia. The only other crayfish currently reported for the upper and middle St. Johns basins is *Procambarus paeninsulanus*, which appears to reach the southern limits of its distribution in central Florida (and may not extend south into the upper St. Johns basin). Other crayfish taxa are found in the lower St. Johns River basin, but impacts to these will largely be due to alterations in salinity due to freshwater flow reductions, or to alterations in hydrology of the tributaries due to land use changes, not flow reductions in the main river.

Studies of the ecology and life history characteristics of *P. alleni* and *P. fallax* have been conducted in the Everglades (Hendrix and Loftus 2000 and references therein; Acosta and Perry 2001, 2002; Dorn and Trexler 2007), in isolated wetlands in south Florida (Huffman 2002), and in marshes of the upper St. Johns basin (Jordan et al. 1996a; 1996b). These studies are summarized here and based on their results, hydrologic habitat criteria are proposed for consideration in future development or modification of Minimum Flows and Levels (MFLs) or regulation of surface water withdrawals.

In the Everglades, *P. alleni* prefers wetlands with hydroperiods generally < 9 to 10 months per year (as defined by Hendrix and Loftus 2000), while *P. fallax* prefers wetlands with longer-duration hydroperiods (11 to 12 months per year after Hendrix and Loftus 2000). This distributional pattern appears to be also true in marshes of the upper St. Johns basin, as *P. alleni* was significantly more abundant (by both density and biomass) in shorter-hydroperiod wet prairies vs. wetter sloughs (Jordan et al. 1996a). *P. alleni* is a more effective burrower, has a higher growth rate, and appears to more effectively exploit shelter/refuge space (Dorn and Trexler 2007).

Data collected by Water and Air Research for the SJRWMD (Figure 1) in the Blue Cypress Marsh Conservation Area (BCMCA) indicates that *P. fallax* was most abundant in *Panicum* marshes. Longer-duration wetlands with deeper water (permanently inundated), such as water lily marsh, supported low numbers of *P. fallax* (Figure 1), probably because of a higher abundance of fish predators such as bass and sunfish (Evans et al. 2004; Jordan et al. 1996b). Dorn and Trexler (2007) indicated that the distribution of *P. alleni* and *P. fallax* reflected a mix of hydrologic requirements, ability to tolerate wetland dry down, competition and predation susceptibility, with *P. fallax* found in deeper wetland habitats.

Dorn and Trexler (2007) showed that *P. fallax* was more abundant in areas of deeper water towards the center of sloughs in the Everglades (average depth of 40 cm). *P. alleni* density was highest in shallower areas of the Everglades sloughs, with data indicating highest density in areas generally <30 cm in depth (Figure 2; Dorn and Trexler 2007). Highest abundance of *P. fallax* was in intermediate water depths in BCMCA in the upper St. Johns basin (Figure 3). These were the depths found in *Panicum* marshes, which suggests that this crayfish is utilizing more densely vegetated habitat, even though depth appears to be shallower than preferred, as shelter from predation. Note that the BCMCA data were from a one-time sampling and do not reflect long-term hydrologic conditions. *P. alleni* may be more resistant to predation due to its being a better burrower, preference for shallower marsh and wet prairie areas (which fish are less able to use), and better ability to compete for shelter (Dorn and Trexler 2007).

Acosta and Perry (2001) evaluated the impacts of shortened hydroperiod (duration of inundation) and depth to groundwater during droughts on populations of *P. alleni* in marl prairie habitats in the Everglades. Abundance and mean size of crayfish were higher in medium (defined as 7 months of inundation) and long (defined as 9 months of inundation) hydroperiod sites than at short (3 months) hydroperiod sites. Groundwater levels during the dry season dropped to >1 m below ground surface at the short hydroperiod site, which significantly affected crayfish survival during the dry season – none were able to survive because they could not burrow deep enough to reach groundwater. Based on their data, Acosta and Perry (2001) suggested that survival of *P. alleni* populations required $\geq$ 7 months of inundation and a seasonal low groundwater table of 0.5 m below ground surface.

Based on the above results, Table 1 indicates the hydrologic and habitat requirements proposed to maintain healthy populations of these two crayfish in headwater and floodplain marshes of the upper and middle St. Johns River. Conservation of *P. alleni* is important because of its endemic status in Florida. Conservation of *P. fallax* is important because its hydrologic and habitat requirements may make it a more readily available (and important) food item in the diets of predators which target crayfish prey. Because of its apparent inability to tolerate wetland dry down as well (Dorn and Trexler 2007), areas of deeper depth (> 0.3 m) appear to be needed to support continued existence of *P. fallax* populations, although it is capable of living in shallower depths (Figure 3). Hydrology appears to exert influences on these two crayfish both directly (via their ability to tolerate dry down during droughts) and indirectly via effects on plant community structure (species composition, stem density, etc.).

Apple Snail. The Florida apple snail (*Pomacea paludosa*) was identified as a target taxon because of its importance in the diets of many wetland taxa of conservation interest, particularly the Everglades snail kite (*Rostrhamus sociabilis plumbeus*), a raptor on both the Federal and State Endangered Species Lists. This bird has expanded its range northward from south Florida into the upper St. Johns River Basin (USJRB), due in part to the restoration of the headwater marsh areas in the USJRB (Miller et al. 1996). Apple snails are a principal component of its diet (Turner et al. 2001; Sykes 1978). Apple snail may also be a good general indicator of wetland health, since they respond both to hydrology (duration of inundation, periods of dry-down, and water depth) and to wetland plant community composition. In particular, broad-stemmed wetland plant taxa are required for oviposition and to allow the snails to “aerial breath” during times of hypoxic stress in the water (Turner et al. 2001; Turner 1996; Karunaratne et al. 2006).

Studies on apple snail life history and ecology have been conducted in the Florida Everglades (Karunaratne et al. 2006) and in the USJRB (Turner 1994, 1996; Stevens et al. 2002; Darby et al. 2003; Darby et al. 2008). A literature review and synthesis of Apple snail biology and ecology was compiled by Turner et al. (2001). Apple snails are found in Florida in both flowing water and lentic (lake and wetland) habitats (Turner et al. 2001). Spring run streams or streams heavily influenced by groundwater inflow appear to be optimal habitats, probably due to a combination of abundant dissolved calcium (for shell construction), good oxygen levels due to turbulent mixing, and an abundance of submerged and emergent plants for feeding, protection from predators, and oviposition. Apple snails possess both gills and a vascularized respiratory chamber called a “lung” (Turner et al. 2001). During periods of reduced DO in the water column, they are able to ascend emergent vegetation to breath air on the surface. This ability is particularly important in wetland habitats, which experience seasonal hypoxia during warm weather and higher water temperatures (Stevens et al. 2002).

Apple snails also require emergent vegetation to lay their eggs. Eggs are deposited in clusters (clutches) on the stems of emergent plants above the water line (Turner 1994, 1996). It appears this is primarily to protect the eggs from aquatic predators (Turner et al. 2001). Turner (1996) found that certain wetland habitats in the USJRB were more optimal for egg clutch deposition; these included edge of sawgrass marsh and shallow marsh areas with an abundance of broad-stemmed plants (> 6mm diameter at the water surface). These included sawgrass (*Cladium jamaicense*), swamp lily (*Crinum americanum*), pickerelweed (*Pontedaria cordata*) and lance-leaf arrowhead (*Sagittaria lancifolia*). In the Everglades, Karunaratne et al. (2006) found higher densities of apple snail in wet prairie habitat (dominated by maidencane, *Panicum hemitomon*, and sedges) versus slough habitat (dominated by fragrant water lily, *Nymphaea odorata*). In part this pattern appeared to be due to a combination of more food resources (epiphytic algae) available in the wet prairie and better screening from visual detection by foraging snail kites. In the Everglades wet prairie habitats, maidencane appeared to be preferred for oviposition (Karunaratne et al. 2006), based in part on its being a dominant plant in those habitats (and apparently preferred over sedges, *Eleocharis* spp.), but they found that arrowhead was used, when available, as well as swamp lily in slough habitat.

Review of the literature discussed above indicates that hydrology exerts a major effect on apple snail populations indirectly, by influencing wetland plant community structure (Darby et al. 1997; Karunaratne et al. 2006). Recent study indicates the snails are well-adapted to tolerate periodic dry downs in wetlands (Darby et al. 2003; Darby et al. 2008), and although they appear to avoid deeper marsh habitat (water lily sloughs), these may be used as temporary refugia during dry seasons (Turner 1996). The major indirect effect of hydrology on apple snail appears to be through how it influences the plant community composition of wetlands (interacting with other environmental forces, such as fire); hydrologic changes which reduce the abundance and cover of plant taxa preferred for oviposition will negatively impact apple snail populations (Turner 1996).

Direct effects of hydrology on Apple snail were shown by Darby et al. (2008) to act via timing and duration of dry down events. Pre-reproductive adult snails were able to survive up to 12 weeks of dry (non-flooded) conditions in mesocosm experiments (Darby et al. 2008). Survival of juvenile snails under dry down conditions was lower than adults. A summary of recommended hydrologic and habitat requirements is presented in Table 2.

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Table 1. Hydrologic and habitat requirements for *Procambarus alleni* and *Procambarus fallax* in the St. Johns River basin wetlands.

	Mean water depth (m)	**Duration of inundation (months)**	**Dry season water table depth (m)**	**Preferred habitats**
P. alleni	≤ 0.3[1]	>7-10[2, 3]	≤ 0.5[2]	Shallow marshes; wet prairies[4]
P. fallax	0.3-0.5[1]	≥ 11[3]	NA	Well-vegetated deep marshes; sloughs w/ dense submerged and emergent vegetation cover[4]

1 – Dorn and Trexler 2007; 2 – Acosta and Perry 2001; 3 – Hendrix and Loftus 2000; 4 – Jordan et al. 1996a; Evans et al. 2004

Table 2. Apple snail hydrologic and habitat requirements in the St. Johns River basin.

	Adult	**Juvenile**
Dry-down duration	< 12 weeks[1]	4 to < 8 weeks[1]
Dry-down timing	Minimize between April-June (during egg-laying/recruitment)[1, 2]	Minimize between May-July (support juvenile recruitment)[1, 2]
Recurrence interval	2-3 years[1, 2]	Same as for adults[1, 2]
Habitat	Mixed shallow marsh (w/ sawgrass, pickerelweed, arrowhead, lily and maidencane[3, 4]	Same as for adults[3, 4]

1 – Darby et al. 2008; 2 – Darby et al. 2003; 3 – Karunaratne et al. 2006; 4 – Turner et al. 2001

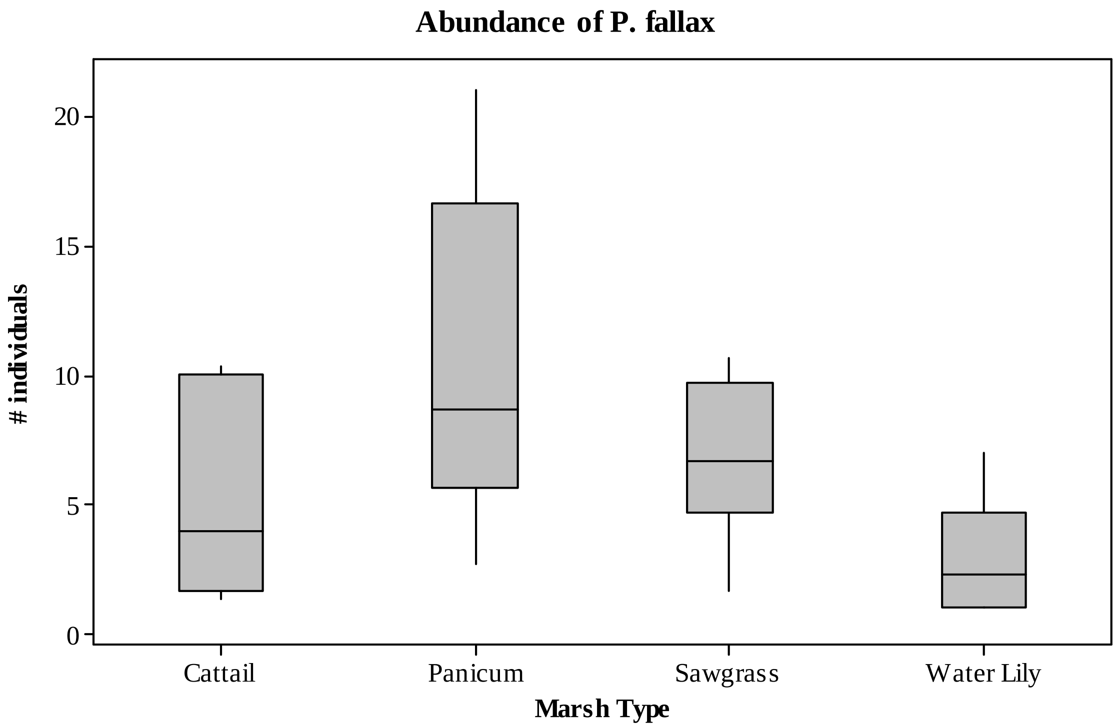

Figure 1. Boxplots (median, interquartile range, and ± 1.5 standard deviations) of abundance of *Procambarus fallax* in major marsh types in the Blue Cypress Marsh Conservation Area in the Upper St. Johns River basin. Data from Evans et al. (2004).

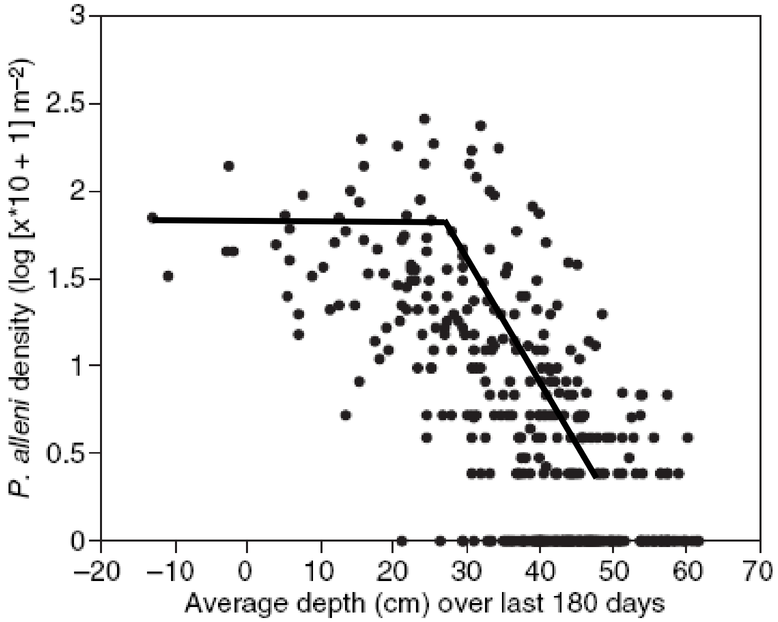

Figure 2. Density of *P. alleni* versus average water depth over the prior 180 day period in Taylor Slough in the Everglades. Adapted from Dorn and Trexler 2007. Line was fit by hand.

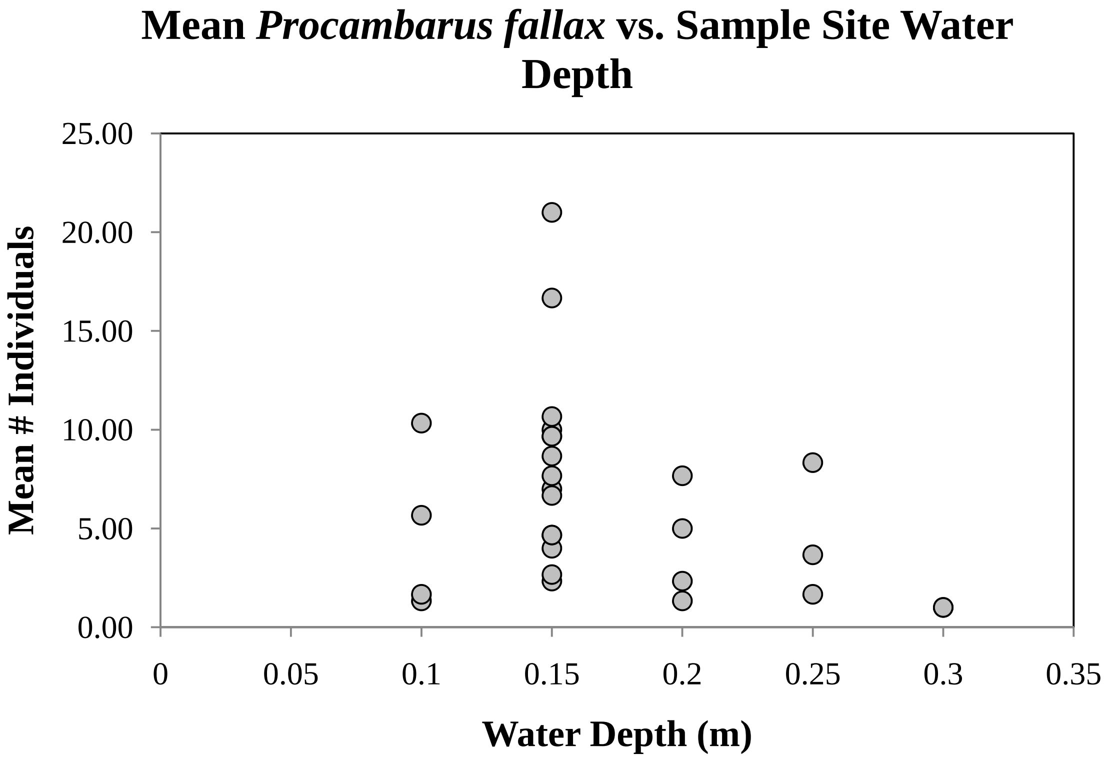

Figure 3. Mean abundance of *P. fallax* versus water depth (single measurement) at sampling sites in the Blue Cypress Marsh Conservation Area. Data from Evans et al. (2004).