Life History Requirements of Two Candidate Waterfowl Indicators for the Kissimmee Chain of Lakes (KCOL)

Life History Requirements of Candidate Indicators

The two waterfowl indicators examined are the Florida mottled duck (*Anas fulvigula fulvigula*) and ring-necked duck (*Aythya collaris*). The mottled duck was chosen because it is commonly found on the KCOL and its habitat requirements are similar to those of many of the dabbling duck species that migrate through and winter on the KCOL each year. By providing quality littoral zone habitat for the non-migratory mottled duck throughout its annual cycle, the habitat requirements for other dabbling duck species during migration and winter would also largely be met. The ring-necked duck, which commonly occurs during fall and winter on the KCOL, was chosen as an indicator to represent the group of ducks known as diving ducks. Florida supports a large proportion (upwards of 22%; Bellrose 1980) of North America's ring-necked ducks during winter. Thus, having adequate wintering habitat for this species in the state is important to the well being of the continental ring-necked duck population. The ring-necked duck is the most numerous species in Florida’s waterfowl sport harvest and the most abundant and widespread diving duck species using freshwater wetlands in the state. This document describes life history requirements for both mottled ducks and ring-necked ducks and critical linkages between particular life history stages and freshwater aquatic habitat characteristics (vegetation type, substrate type, areal coverage, etc.).

Mottled Duck

Florida’s mottled ducks are nonmigratory and inhabit inland emergent wetlands in peninsular Florida, including those within the KCOL wetland complex. In this area, FWC biologists (during aerial surveys, leg-banding efforts, and radio telemetry monitoring) have observed mottled ducks using the littoral zones of lakes during all periods of the birds’ annual cycle. Florida mottled ducks breed and nest predominantly from March through June (Gray 1993, Bielefeld and Cox[b]), but copulations have been observed as early as the beginning of December. Females nest mainly in upland grass areas or other dense vegetative cover within 1 km of wetlands and have been observed with broods at night and during the day in lake littoral zones (Gray 1993, Bielefeld and Cox[b]). During the flightless, wing-molt period, mottled ducks commonly congregate on large wetlands, including littoral zones of lakes. Wing-molt in males may occur as early as June, but females undergo wing-molt after their reproductive effort is complete, usually in late July through mid-September (Moorman and Gray 1994). During winter, mottled ducks use littoral areas for diurnal activities such as foraging and loafing (Bielefeld and Cox[b]).

Mottled ducks favor shallow, emergent wetlands because they provide a combination of food and cover. Mottled ducks feed primarily by tipping-up; therefore, they require relatively shallow water (15-30 cm) to forage effectively (Chamberlain 1960). However, water can be deeper if submersed aquatic plants occur within 30 cm of the surface. The ratio of open water to emergent vegetation should range from 30:70 to 70:30. It is desirable to have the open-water portion support submersed or floating-leaved aquatic plants. At least 30% of the coverage of the emergent vegetation should consist of annual seed-producing plants (e.g., grasses, sedges, and smartweeds [*Polygonum spp.*]; Beckwith and Hosford 1955, 1957). Valuable species of submersed and floating-leaved aquatics include *Nymphaea odorata, Brasenia schreberi, Najas marina, Potamogeton* spp*.,* and *Vallisneria americana* (Beckwith and Hosford 1955, 1957; Stieglitz 1972; O'Meara et al. 1982). Emergent vegetation should be interspersed among open water areas forming a mosaic of patches varying in size and shape. These conditions often provide abundant invertebrates, which can be an important food source. Good interspersion of vegetation also provides visual barriers for mottled duck pairs during the breeding season, a time when pairs defend territories.

Ring-necked Duck

Ring-necked ducks generally arrive in significant numbers in Florida sometime in November and remain until early March (Montalbano and Johnson 1986). During winter, ring-necked ducks require habitats that can provide adequate food and protective cover. The foraging habitat objective for ring-necked ducks should have water depths of 30-180 cm (Chamberlain 1960). Fifty percent of the area should be no deeper than 120 cm. Ring-necked duck foraging habitat should contain at least 70% coverage of submersed aquatic or floating-leaved vegetation. Food plants valuable to this species include *Nymphaea odorata, Brasenia schreberi, Najas marina, Potamogeton* spp*., Vallisneria americana,* and *Hydrilla verticillata* (Montalbano et al. 1978, Johnson and Montalbano 1984). Submersed aquatics should reach the water surface for highest value to ring-necked ducks. These plants provide food directly and indirectly as substrate for invertebrates. Large areas of hydrilla matted on the surface provide valuable habitat for ring-necked ducks, which eat all parts of this plant.

Some ring-necked ducks use emergent wetlands for roosting. Consequently, habitats with characteristics like those favored by mottled ducks should provide ring-necked ducks with suitable roosting areas.

General relationships between candidate indicators and required habitat

Mottled Duck

During wing-molt and brood rearing, mottled ducks frequent shallow water areas with exposed mudflats or hummocks for loafing (LaHart and Cornwell 1970, Gray 1993, Bielefeld and Cox[b]). These areas also are characterized by an abundance of emergent vegetation that provides protective cover during the day and an abundant invertebrate food source. During the breeding season, mottled ducks use shallow water habitats with discrete areas of open water and abundant emergent vegetation (bulrush, cattails, sedges, rushes, grasses) located near upland areas with dense vegetation (Lotter and Cornwell 1969, Johnson et al. 1991, Bielefeld and Cox[b]). Shallow water provides foraging areas, while discrete open-water areas within emergent vegetation provide habitat that can be defended from other breeding pairs. During the post-breeding and winter periods, mottled ducks use a variety of wetland habitats with the aforementioned water depths and characterized by emergent vegetation interspersed with areas of open water and submersed aquatic plants (Johnson and Montalbano 1984, Bielefeld and Cox[b]).

Ring-necked Duck

During November through March, ring-necked ducks use open-emergent to open-aquatic-bed wetlands with water depths in the aforementioned range for foraging and loafing habitat (Johnson and Montalbano 1984). For roosting, ring-necked ducks often use emergent wetlands with shallower water, similar to those favored by mottled ducks.

Linkages between candidate indicators and water level fluctuations

Mottled Duck

A study of mottled duck ecology in the Upper St. Johns River Basin indicated that recruitment and survival were lower in drought years (Bielefeld and Cox[a]). During this study, mottled ducks experienced high mortality when surface waters receded during the wing-molt period. After wing-molt, when mottled ducks regained flight capability, they responded to wetland drying by moving to areas with adequate water. Birds moved from rural areas to urban/suburban areas presumably because man-made/altered wetlands in these areas held water through the drought. Such movements into urban/suburban habitats can pose a risk to mottled ducks because they more frequently come into contact with feral mallards. This close contact likely increases the probability of interbreeding and hybridization between the two species.

High water also can cause mottled ducks to move out of an area if water becomes too deep to allow effective foraging or if some other habitat requirement (e.g., lack of dry loafing or nesting areas) is negatively affected. However, if high water results in greater wetland surface area, productive habitats maybe be inundated and made available. No negative effects on mottled duck survival or recruitment have been linked to over-abundant surface water.

Rapid and dramatic changes in water levels retard the growth of annual seed-bearing and submersed aquatic plants and can flood or dewater other important areas such as loafing, nesting, and brood-rearing sites. Consequently, large, rapid fluctuations in water level can have negative effects on mottled ducks irrespective of when the changes occur during the annual cycle. This is not to say that water levels should be stabilized within a system for long periods of time, as such conditions promote low wetland productivity. In general, the historic hydrology for the area should be emulated whenever possible to promote diversity and productivity over the long-term.

Ring-necked Duck

During winter, low water levels may reduce overall available habitat for ring-necked ducks, especially loafing sites. However, if low water levels result in an abundance of hydrilla or other desirable submersed aquatic plant foods on or near the surface, then an increase in foraging habitat will result, likely benefiting these birds. Conversely, high water levels likely increase the overall availability of habitat for ring-necked ducks, but foraging habitats may be limited if water depths in the areas with desirable plant foods surpass the aforementioned maximums. If water levels increase or decrease rapidly to levels that preclude effective foraging or eliminate loafing sites, ring-necked ducks likely will move to better habitat.

Specific Recommendations

Mottled ducks

- During February-September, littoral zones of lakes should provide emergent and submersed aquatic plant habitats, with water depths of 15-30 cm, and have a ratio of open water to emergent vegetation between 30:70 and 70:30. Fluctuations in water level should be minimal during this period, but a slow dry-down during February-May, emulating the normal dry season, would be optimal to promote productivity of these habitats. A rapid dry-down during July, August, and September, which would concentrate both flightless mottled ducks and predators, should be avoided to minimize mottled duck mortality.

- During October-January, similar habitats should be available as managed for during February-September. A slow dry-down starting in November and emulating the historic decease in water levels associated with the onset of drier winter weather would be desirable.
- At least 30% of the coverage of emergent vegetation should consist of annual seed-producing plants (e.g., grasses, sedges, and smartweeds [*Polygonum spp.*]). Valuable species of submersed and floating-leaved aquatics include *Nymphaea odorata, Brasenia schreberi, Hydrilla verticillata, Najas marina, Potamogeton* spp*.,* and *Vallisneria americana*.
- Emergent vegetation should be interspersed among open water areas forming a mosaic of patches varying in size and shape.

Ring-necked Ducks

- During November-February, portions of the littoral zones of lakes should be flooded from 30-180 cm in depth and support dense (70% coverage) submerged aquatic plants. Drastic fluctuations in water level that preclude the establishment and vigorous growth of and access to submerged aquatic plants by ring-necked ducks should be avoided. A slow dry-down during this period that results in new submerged aquatic plants becoming accessible to ring-necked ducks would be optimal.
- Plants valuable to this species include *Nymphaea odorata, Brasenia schreberi, Najas marina, Potamogeton* spp*., Vallisneria americana,* and *Hydrilla verticillata;* and they are most valuable when they reach the surface of the water.

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Life History Requirements
of American Alligator (*Alligator mississippiensis*)

Life History Requirements

The American alligator was chosen as an indicator species because of the significant and important role it has in Florida's natural resources and culture. This species has a well established history dating back thousands of years. Ecologically, the alligator is known as a top predator in freshwater aquatic habitats. It also has helped shape some wetland ecosystems and affected the associated wildlife with activities such as nest construction and the creation and use of "gator holes." Culturally, including economically, this species has played an important role with early European as well as Native American civilizations, which utilized alligators and their hides for food and trade. The importance of the alligator is evident even today in Florida with recreation, tourism, and business. In 2001, more than 13,000 wild alligators were harvested in Florida by nuisance, recreational, and commercial trappers for an estimated meat and hide value in excess of $4.3 million (Dutton et al. 2002). Also in 2001, 63 alligator farms in Florida harvested over 25,000 alligators with an estimated value in excess of $3.8 million (Dutton et al. 2002). The significance of this species is also recognized symbolically as Florida's official state reptile.

Alligators begin breeding activities in April and May as the weather warms up and they emerge from the winter period of relatively little activity. After mating, females move into available marsh habitat to construct a nest and deposit eggs. Nest construction consists of the female forming a dome-shaped mound of vegetation, muck, peat, and soil by using her tail and mouth as construction tools. Typical nests are approximately two feet high and five or six feet wide. Suitable nesting habitat includes dense emergent marsh, such as cattail (*Typha spp.*) or sawgrass (*Cladium jamaicensis.*), with an organic or soil substrate that is sufficient to support the majority of the nest above the water line. Alligator nests are also used by other reptiles for nesting sites, further supporting their use as an indicator species. In particular, Florida red-bellied turtles (*Chrysemys nelsoni*) frequently use alligator nests as nesting sites (Goodwin and Marion 1977; Kushlan and Kushlan 1980).

A nesting female will deposit 20-60 eggs into a hole in the top of the nest and cover the clutch with nest material. After egg deposition, the eggs will incubate for approximately 65 days. The emergence of hatchling alligators from their eggs begins in early or mid-August, and continues through early September. Hatchlings will remain near the nest, taking refuge in the water and vegetation, and feeding on small prey such as insects and minnows. During this period, the adult female will also remain in the vicinity of the nest.

Hatchlings will begin to disperse after about a year. Because of their small size (approximately 30-40 cm), they will continue to spend most of their time in or near dense emergent vegetation. As they grow larger, they spend more time utilizing deeper and more open waters where adequate food sources can be found.

Life History Links to Habitat

An important consideration for maintaining a sustainable wild alligator population is ensuring adequate nesting habitat. Alligators will utilize a variety of substrates for nesting, but the most productive nesting sites are often associated with the more eutrophic aquatic systems with extensive dense emergent marsh areas. Nest construction is a complex exercise in which the female creates a dome of vegetation, peat, and/or soil by knocking down and mounding the surrounding materials. Percival et al. (1992) found alligators constructing nests from a variety of plants, but dominant species on their study sites included sawgrass, giant reed (*Phragmites spp.*), and cattail. However, they also suggest that nest material might affect the viability of eggs. They found that the viability of eggs was lower in nests composed of arrowhead (*Sagittaria latifolia*) than other nest materials, possibly because of its relatively higher water content, decomposition, and compaction than other materials.

One of the threats to alligator nesting success is nest flooding (Goodwin and Marion 1978; Mazzotti and Brandt 1994). Joanen et al. (1977) found that eggs submerged in water for more than 48 hours resulted in 100% embryo mortality. Such conditions could occur in the wild if water levels rise too high before the eggs are able to hatch. Dense emergent marsh at higher elevations likely contributes to increased survival of alligator eggs. Such habitat is created over time by organic build up. Rice (1992) found that alligators nested at higher elevations on Lake Okeechobee. He noted that these areas provide a buffer from high waters, which could flood nests and increase mortality of the embryos.

Another factor that has an impact on the survival of wild alligator eggs is predation. Common predators of alligator eggs include raccoons (*Procyon lotor*), river otters (*Lutra canadensis*), and wild hogs (*Sus scrofa*). Studies have reported raccoons to be the primary predators of alligator eggs (Deitz and Hines 1980; Goodwin and Marion 1978). It is suggested that nests constructed in marsh locations, away from levees and the shoreline, are less likely to be destroyed by raccoons (Kushlan and Kushlan 1980; Mazzotti and Brandt 1994).

Dense emergent marsh might also be important for the survival of hatchling alligators. In the process of constructing a nest in this type of habitat, the female often creates a small pool of water around the nest, as well as one or more water trails created by her movement to and from the nest. Woodward et al. (1987) noted that these pools and trails might increase the survival of hatchlings by providing a refuge for them during their first few months. The open water of the pools and trails provide the hatchlings opportunities to feed on small fish and insects without straying far from the cover of the dense vegetation.

Although dense emergent marsh provides good nesting habitat for alligators and cover for hatchlings, a diversity of wetland habitats is beneficial for alligator populations as a whole. In general, the dominant food type changes from invertebrate to vertebrates as alligators increase in size (Delany and Abercrombie 1986; Delany 1990; Delany et al. 1999; Mazzotti and Brandt 1994). Small alligators feed primarily on invertebrates, small fish and herptiles. Such prey is often abundant in and near emergent marsh. As alligators grow larger, their diet shifts to larger prey such as turtles and larger fish, most of which are more available in deeper, open water. Adult male alligators (>180 cm) have been shown to spend more time in open water than swamps during the summer (Goodwin and Marion 1979), possibly influenced by the availability of the preferred prey in this habitat.

Life History Links to Water Levels

As noted earlier, flooding is one of the greatest threats to the survival of alligator eggs. Alligators begin constructing nests in late May and early June. Peak nesting occurs during mid-June to early July (Deitz and Hines 1980; Goodwin and Marion 1978). Eggs incubate for approximately 65 days before hatching in August through early September. Although female alligators might adapt nesting heights to water levels at the time of nest construction, significant increases in water levels during the nesting period can flood nests and increase mortality of embryos.

Low water levels can also affect survival. Normal and high water levels allow alligators to disperse into their preferred habitats. Under these conditions, they will typically remain spatially distributed by size, with smaller alligators inhabiting marsh habitats and larger alligators spending more time in open water. Low water levels such as during droughts however, concentrate alligators of all sizes into the remaining water, resulting in increased fighting and vulnerability to cannibalism (Mazzotti and Brandt 1994; Woodward et al. 1987). The increased stress associated with these conditions could potentially have negative impacts on the reproductive cycle of female alligators if low water occurs during the fall. Although most of the obvious reproductive activity (i.e., mating, gravidity, and nesting) occurs during the spring, Guillette et al. (1997) found that vitellogenesis (synthesis of the yolk protein vitellogenin and its incorporation in the cytoplasm of the oocyte) and associated processes occur in September and October. Therefore, it is possible that extreme low water levels during this time would increase stress for reproductively active female alligators and disrupt the reproductive cycle.

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Life History Requirements of Snail Kite

Life History Requirements and Links to Habitat

The snail kite (*Rostrhamus sociabilis*) is an endangered raptor whose distribution in the United States is restricted to the South Florida Ecosystem, including waters of the Everglades, Lake Okeechobee, Kissimmee River, Upper Kissimmee Chain of lakes (KCOL), and Upper St. Johns River. Prior to 1996, most kite nesting in the KCOL occurred on Lake Kissimmee (average of 31 nests/year), with lesser numbers on Lake Tohopekaliga (Lake Toho) and East Lake Tohopekaliga. Large influxes of kites have been observed nesting on Lake Toho primarily during drought events on Lake Okeechobee and the water conservation areas of southern Florida (e.g., 1991 with 182 of 223 nests recorded during 1987-1993; Rodgers, unpublished data).

Nesting occurs primarily from January through August. Egg-laying takes place from 14 January to 8 July and young are typically fledged from March 28 to September 16. Snail kites nest in flooded vegetation, of either woody (southern willow, *Salix sp.*; buttonbush, *Cephalanthus occidentalis;* cypress, *Taxodium* sp.) or non-woody (cattail ,*Typha* sp.; bulrush, *Scirpus* sp.) species. Water depth at nest site varies by lake and substrate. Average water depths at nest sites ranged from 36-93 cm and were recorded as follows: East Lake Toho: bulrush 53 cm, cattail 93 cm, willow 71 cm; Lake Toho bulrush 92 cm, cattail 88 cm, willow 59 cm; Lake Kissimmee bulrush 93 cm, cattail 87 cm, willow 57 cm, buttonbush 36 cm.

Historically, cattails were not present in substantial acreage in the KCOL, and kites nested in woody vegetation. Currently, only high lake levels (14.75 m and above) provide notable access to flooded woody vegetation (along the lake margins) on all lakes. During normal pool and low lake levels (14.5 m or below), most nesting occurs in non-woody species (cattail and bulrush) farther out in the littoral zone or, on Lake Kissimmee, in woody species in regions around Bird and Rabbit Islands. Large, dense stands of cattail can provide protection/buffer from human disturbance (recreational activities) and from wind and wave action. Nests located in dense, matted cattail stands have reduced risks of nest failure due to collapse as compared with nests in less dense or smaller patches of cattail. The average clutch size for kites is 2.77 ($\pm$ 0.50), but varies among lakes and years. Average fledgling success is 0.87 ($\pm$ 1.00)/nest, but again there is considerable inter-year and inter-lake variation.

Snail kites feed primarily on Florida apple snails (*Pomacea paludosa*) that are present in the upper 5 cm of the water column, typically attached to emergent vegetation. Typical foraging habitat for kites consists of large expanses of spikerush (*Eleocharis* sp.) or maidencane (*Panicum hemitomon*) interspersed with open water, such that kites are able to visually locate snails.

Impacts of Low and High Water

Impacts of Low Water

Low water levels impact kites directly (via nesting substrate) and indirectly (via access to snails). Low water levels do not provide nesting kites access to flooded woody vegetation, which is less likely to collapse during high winds. Nesting in non-woody substrates, such as cattail or bulrush, increases the probability that the nest will either collapse during windy conditions or fall over when the stem buoyancy is lost. Low water levels also reduce access to snails by either causing the snail to burrow in the bottom sediments or matting down the emergent vegetation and reducing the visual location of snails by the kites. Finally, lack of water or lower lake levels may provide predators (snakes and raccoons) access to the nests, which might be reduced by either deeper water or the presence of alligators (in deeper water).

Impacts of High Water

High water has both positive and negative effects on kites. Higher water levels provide flooded woody nesting substrates, such as willow, buttonbush and cypress. However, prolonged inundation will ultimately weaken and cause the death and reduce germination of these aquatic woody species.

Specific Recommendations

Lake water levels should fluctuate from year to year to allow both access to flooded woody vegetation and adequate foraging habitat as described above. These fluctuations should be similar to normal drawdown schedules of unregulated lakes so that water levels are high in the late winter and early spring and decrease during the dry season of the year. Extreme high or low water events are not incompatible with snail kites, provided that they are infrequent (i.e., they do not occur in multiple years). Kites have demonstrated an ability to cope with these events by adjusting the location then nest in a particular lake or by nesting in other wetlands during these years.

Apple Snail

Life History Requirements and Links to Habitat

The primary food source of the endangered snail kite (*Rostrhamus sociabilis*) is the Florida apple snail (*Pomacea paludosa*). This operculate gastropod inhabits a variety of aquatic habitats, but primarily occurs in wetlands that experience periodic dry downs (Cowie 2002). Ongoing water level and aquatic plant manipulations have direct impacts on apple snail populations, which in turn affect snail kite populations.

Although egg clusters can often be found from February – November, the majority of egg production occurs from March –June and in central Florida most often peaks in April-May (Darby et al. 1999). Female apple snails deposit (oviposition) their 3-6-mm diameter eggs in clusters on emergent substrates above the water surface (Hanning 1979, Turner 1996). Egg clusters are laid approximately 9-25 cm above the water surface which reduces the potential for eggs to become submerged should water levels rise during the two to three week incubation period. Flooded eggs do not develop (Turner 1994).

Snail eggs can be found on a variety of substrates ranging from emergent vegetation with thick stems (such as *Cladium, Sagittaria,* and *Typha*) and less frequently on species with thinner stems, like *Panicum* (Wallace et al. 1956) and *Paspalidium* (Darby, unpublished data). Turner (1996) thought that narrow stems bend under the weight of the apple snail, especially in the aerial part of the stem. In cases where female snails have deposited eggs on narrow stems (< 6-mm in diameter), egg clusters are located closer to the water surface, even though the thin emergent stems have a greater height (Turner 1996). This may increase the likelihood of flooding and subsequent destruction of the eggs. Therefore, the particular structure of the emergent species available may affect the suitability of a habitat to support apple snails, at least for oviposition. More robust emergent vegetation likely provides better oviposition substrate than thin-stemmed plants.

Little conclusive evidence exists on the food preferences of apple snails (Sharfstein and Steinman 2001). Some authors classify them as consuming macrophytes (Sheldon 1987), and others indicating they are microphagous grazers and scavengers (Branson 1961), or zoophagous (Estebenet 1995). Apple snails have been observed eating *Echhornia crassipes* (Talbot 1970), *Chara* (Hurdle 1973), *Naias marina* (Hurdle 1973), and *Utricularia* sp. (Martin 1973). However, Darby (pers. com.) points out that apple snails in aquaria eat most any macrophyte provided, including spinach and lettuce. In terms of availability, wetlands in peninsular Florida that support a variety of submerged and emergent species coated with varying amounts of periphyton should provide adequate forage for apple snails as Sharfstein and Steinman (2001) recognized that grazing periphyton would result in macrophyte consumption as well.

Apple snails in Florida routinely experience fluctuating water levels and dry down conditions under natural hydrologic regimes (Darby et al. 2002). As the water levels in wetlands recede, the apple snails are subjected to higher water temperatures and low dissolved oxygen levels, and in extreme cases they experience desiccation during dry downs as noted for other species of apple snails (Burky et al. 1972, Haniffa 1978, Aldridge 1983). Faced with a drying event, apple snails must acclimate, migrate, or aestivate (Aldridge 1983). In general, freshwater snails collectively employ all of these strategies to survive harsh environmental conditions (Burky et al. 1972, Medcof 1940, Haniffa 1978). Although Florida apple snails experience these conditions, how they adapt to them has only recently been studied. Darby et al. (2002) studied snails bearing transmitters and discovered that apple snails move sufficient distances to potentially find deep water refugia as water levels decline, but they were not successful at avoiding dry downs, as many were subsequently stranded. When waters receded to a depth of 10-cm, apple snails responded by stopping all movements and soon become stranded in dry marsh (Darby et al. 2002).

Some species in the apple snail family (Ampullariidae) are known to aestivate for 3 to 25 months during dry conditions (Little 1968, Burky et al. 1972, Haniffa 1978, Chandrasekharam et al. 1982, Cowie 2002). During aestivation, the operculum serves as a barrier to water loss (Meenakshi 1964). Several reports indicated that *P. paludosa* is incapable of tolerating dry downs (Little 1968, Kushlan 1975, Turner 1994), and this has been one reason snail kite researchers have called for avoiding drying events (Beissinger 1988, Sykes et al. 1995). Recently, however, Darby et al. (2003) found that earlier reports of a lack of dry down tolerance in Florida apple snails was confounded by an annual spring die-off (regardless of hydrologic conditions). Through a series of simulated marsh drying events in a laboratory setting, Darby and Percival (2000) reported that 75% of adult apple snails survived 3 months of exposure to dry down conditions; 50% survived up to 4 months.

Impacts of Low and High Water

Impacts of Low Water

Dry downs that would likely have a substantial negative impact on apple snails would be those that either (1) take place during the breeding season (March – July), especially during April-May or (2) exceed 3 months in duration. Darby et al. (2004) concluded that the 6-month drying event in the majority of the Lake Kissimmee littoral zone resulting from the 1995-1996 drawdown exceeded the capacity for apple snails to survive by aestivation. Apple snails cease moving (and therefore laying eggs) when water levels fall below approximately 10 cm. This drying event encompassed nearly the entire breeding season for apple snails and resulted in a decline in snail abundance of up to 80% (Darby et al. 2004). As a result, recruitment of juveniles in to the Lake Kissimmee snail population was also dramatically reduced.

During extreme dry downs, the primary emergent vegetation available is *Paspalidium*. This habitat (1) has a limited number of snails (as compared with higher elevation littoral zone habitat), (2) is less than ideal for oviposition due to structural weakness, as described above, and (3) snails in this habitat lay fewer eggs (Darby, unpublished data**)**. Snails in areas of the littoral zone with less than 10 cm of water are essentially unproductive, and if these areas dry out for > 4 months, then over 50% of the snail population will likely die. These impacts on the overall snail population would be proportional to the percent of the littoral zone dried out (Darby et al. 2002).

Impacts of High Water

High water can impact apple snails in two ways. First, eggs on emergent vegetation in the littoral zone may be flooded and destroyed, resulting in lower recruitment. Second, emergent vegetation ideal for oviposition may be flooded such that it becomes unavailable for oviposition, resulting in reduced egg-laying.

Specific Recommendations

We recommend that in most years during the breeding season (March – June) the littoral zone elevations that support *Pontederia cordata* be flooded $\geq$10cm and not fluctuate more than 15cm in a two or three week period. This would make available the best oviposition habitat that is most common in the littoral zone, and would keep eggs from being flooded and breeding snails from being caught in dropping water levels and forced to aestivate.

Evidence from the Everglades suggests that areas with snail densities below approximately 0.15 snails/m^2 are not used by foraging snail kites (Darby, unpublished data). We recommend that habitats be managed to provide for snail abundance in excess of this level, preferably > 0.25 snails/ m^2. Darby et al. (2004) reported snail densities ranging from 0.22 – 2.84 snails/ m^2 on Lake Kissimmee prior to the 1995 drawdown.

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Life History Requirements of Four Candidate Fish Indicators Dependent on Lake Littoral Habitat

Life History Requirements of Candidate Indicators

The four candidate fish indicators examined include largemouth bass *Micropterus salmoides*, bluegill *Lepomis macrochirus*, Seminole killifish *Fundulus seminolis*, and bluespotted sunfish *Enneacanthus gloriosus*. The type and level of dependence on littoral habitats by the four candidate indicators varies, but is critical for the maintenance of their respective populations. Life history requirements are provided for each species and critical linkages of particular life history stages to littoral habitat (vegetation type, substrate type, areal coverage, etc.) are described.

Largemouth Bass

Largemouth bass spawn in Florida from January through May (Hoyer and Canfield 1994). Males excavate shallow nests in littoral zone substrate and remain at the nest through the first few days after hatching to guard eggs and fry from predation. Preferred spawning substrate in Florida is sand; however, firm structure such as aquatic plant roots may be used. Newly hatched fry and juveniles gain protection from predation by associating with both emergent and submergent littoral vegetation. Early life stages feed primarily on small aquatic insects and crustaceans, but undergo an ontogenetic switch to fish prey at about 50 mm TL. Each prey type can be abundant in and adjacent to littoral vegetation. Adult bass most often are found in association with littoral vegetation or with some type of structure in the limnetic zone. Because adult largemouth bass are a sit and wait predator, associating with structure and vegetation aids in success of their ambush feeding strategy.

Bluegill

Bluegill spawn throughout the year, typically from February through October (Hoyer and Canfield 1994). Male bluegill excavate nests in colonies in littoral zone substrate such as sand or other firm structure and guard the eggs to decrease predation. Both juveniles and adults typically associate with littoral vegetation as a refuge from predation. Bluegill are omnivorous and consume a wide range of forage including algae, vascular plants, zooplankton, aquatic and terrestrial insects, and small fish (Hoyer and Canfield 1994). Additionally, much of the forage (particularly invertebrates) that bluegill require are most abundant within littoral vegetation and can therefore be heavily dependent on such habitat.

Seminole Killifish

Seminole killifish are most often associated with the shallow water area (< 1 meter) of the littoral zone. They are often associated with sandy substrate. Seminole killifish spawn primarily in April and May, but spawning can occur throughout the summer months. They feed primarily in mid-water or near the bottom on ostracods, cladocerans, and chironomid larvae (Hoyer and Canfield 1994).

Bluespotted Sunfish

Bluespotted sunfish may spawn through the year. Eggs are laid in thick vegetation or filamentous algae. Major food items are small crustaceans, aquatic insects, plants, worms and mollusks (Hoyer and Canfield 1994). Reproductive strategies for bluespotted sunfish require vegetation, primarily submersed. Food availability and survival from predation due to their small size is heavily dependent on vegetation, primarily submersed. Submersed vegetation is critical in maintaining a large population of bluespotted sunfish.

General relationships between candidate indicators and required habitat

Lake trophic state of a water body is a critical habitat component for fish production. Trophic state (i.e. fertility) of a lake is determined according to Forsberg and Ryding's (1980) water quality parameters which include Chlorophyll-*a*, Total Phosphorus, and Total Nitrogen. Fish abundance has been found to be directly related to the trophic state of a lake (Melack 1976); McConnell et al. 1977; Jones and Hoyer 1982; Hanson and Leggett 1982; Bays and Crisman 1983; Hoyer and Canfield 1996). For example, Hoyer and Canfield (1996) found adult largemouth bass abundance and standing crop in 56 Florida lakes to have a positive linear relationship with lake trophic state up to the eutrophic range. Additionally, lake trophic state is a factor to consider when attempting to predict relationships between the abundance of aquatic macrophytes (vegetation) and the abundance of largemouth bass (Hoyer et al. 1985).

Vegetation coverage within lakes is critical to population dynamics for largemouth bass, bluegill, and redear sunfish. Recruitment (Aggus and Elliot 1975; Durocher et al. 1984; Wiley et al. 1984; Maceina et al. 1995; Hoyer and Canfield 1996; Paukert and Willis 2004) and growth (Colle and Shireman 1980; Trebitz and Nibbelink 1996) of these species can be directly affected.

Maceina et al. (1995) found recruitment for largemouth bass to age-1 in Guntersville Reservoir, Alabama was greatest in vegetated habitats. Relative abundance of largemouth bass tended to increase with emergent vegetation coverage in shallow Nebraska lakes (Paukert and Willis 2004). Durocher et al. (1984) found that submersed vegetation up to 20% coverage resulted in a positive relationship with largemouth bass standing crop recruitment to harvestable size in Texas reservoirs. Wiley et al. (1984) found a parabolic relationship between largemouth bass and aquatic macrophyte standing crop, in which intermediate macrophyte biomass levels produced maximum total yield to the fishery in Illinois ponds. They also found a positive correlation between macrophyte density and invertebrate production, which has a strong implication for fishery productivity since most freshwater fish species consume invertebrates during some part of their life cycle (McKinney and Durocher, date unknown).

Fish growth and condition can be positively or negatively affected by macrophyte coverage. Colle and Shireman (1980) found that high coverage of aquatic macrophytes resulted in lower condition factors for largemouth bass, bluegill and redear sunfish *Lepomis microlophus*. They hypothesized that this was a result of decreased foraging efficiency due to excessive plant cover for forage species. Trebitz and Nibbelink (1996) found that intermediate coverage is optimal for fish growth.

Allen and Tugend (2002) found that largemouth bass abundance increased when plant biomass was less than 5 kg/m^2. Additionally, largemouth bass abundance was higher at an intermediate percent area coverage (PAC) of aquatic macrophytes of 5-90%. They also reported that plant biomass greater than 50 kg/m^2 and 100% PAC resulted in low dissolved oxygen (mean < 2 mg/L), absence of centrarchids and low species richness with only a few species adapted to surface respiration such as the sailfin molly (*Poecilia latipinna*).

Tugend and Allen (2004) reported abundance of seminole killifish increased following a drawdown of lake Kissimmee in 1996 through 2000. Diverse fish communities were present all years as well. They attributed the increase to restoration of quality habitat (i.e. sandy substrate and moderate coverage of aquatic macrophytes) in enhanced areas of the littoral zone.

Aquatic plant species considered to be desirable by FWC fisheries biologists include maidencane *Panicum hemitomon*, Egyptian paspalidium *Paspalidium geminatum*, bulrush *Scirpus californicus*, eleochris *Eleochris* spp., pondweed *Potamogeton illinoensis* and eelgrass *Vallisneria americana* as they provide refuge for fish to spawn, forage and avoid predation. These plant species are also less likely to become invasive (i.e. high density and biomass) and are often rooted in firm substrate. On the contrary, aquatic plant species such as pickerelweed *Pontederia cordata*, cattail *Typha spp.* and tussock plant communities (floating plant communities with organic material associated with them) tend to become invasive under stabilized conditions, resulting in low dissolved oxygen and poor fish habitat. Although these species should be represented in the plant community to increase plant diversity, they must be managed at desirable densities and biomass to achieve optimal littoral zone habitat.

Linkages between candidate indicators, habitat and water level fluctuations

Adequate water level fluctuation including timing, frequency, range and duration, in and of itself, should provide many benefits to fish habitat. Both high and low water events are important for maintaining healthy populations of the candidate indicators as well.

During high water (i.e. flood events) habitat improvements occur when organic material and detritus that had formed within the lake are transported to the floodplain. Additionally, high water combined with wind and wave action often reduces high plant density and biomass. As the water recedes that material remains in the floodplain where it oxidizes and decomposes.

In addition to habitat improvements, high water can have direct effects on fish populations. Potential mechanisms resulting in positive recruitment of indicator species due to higher water levels include an increase in the amount and availability of juvenile fish habitat and food resources through increased inundation of shoreline vegetation (Jenkins 1970; Aggus & Elliot 1975; Keith 1975; Timmons et al. 1980, Miranda et al. 1984; Meals & Miranda 1991; Bonvechio & Allen 2005). Bonvechio and Allen (2005) found that largemouth bass year-class strength was positively correlated with water levels in three central Florida lakes. Potential reasons for these strong year-classes included increased coverage of littoral habitat that resulted in increased availability of habitat, increased food resource (zooplankton, insects and small forage fish), and decreased predation. Furthermore, water level increases during the spawning season is a potential management tool for stimulating largemouth bass spawning in systems where water temperature is suitable (Ozen and Noble 2002). Estes and Myers (1996) found that harvestable bluegill standing crop was positively related to characteristics of water level fluctuations for three Florida lakes.

High water can have indirect effects on fish populations as well. High water resulting in inundation of oxidized soils causes nutrient releases into the water column. This release of nutrients can temporarily stimulate a robust food web that can result in increased growth and high survival of fish species. For example, Estes and Myers (1996) found young-of-the-year black crappie densities were related to annual changes in water levels, but thought this relationship was more the result of incoming nutrients than actual water level changes. Allen and Tugend (2002) reported exceptional growth rates for largemouth bass following a drawdown and refill of Lake Kissimmee in 1996. This increased growth is most likely attributed to increased food availability as a result of increased productivity. Fish survival can be improved by increased growth rates and/or increased vegetation coverage. This can result in strong year classes that can be found within the population for up to ten years or longer. This can indirectly cause a positive effect not only on the fish population, but the fishery as well.

Similar to high water events, low water events (i.e. droughts) are essential to the maintenance of dynamic, healthy fish habitat. During frequent drying events reproduction of plants can be limited and organic material/detritus that had accumulated on the lake bottom oxidizes and decomposes, leaving mineralized soil as the dominant substrate type which is found within the Kissimmee Chain of Lakes. During and soon after a drying event occurs, terrestrial, semi-aquatic, and desirable aquatic macrophytes (such as bulrush, maidencane, eelgrass, and egyptian paspalidium) germinate within the littoral zone.

In addition to habitat improvements, low water events temporarily reduce availability of vegetated littoral habitats, concentrate forage, and increase forage availability for predators such as largemouth bass. This may result in a short or long-term increase in condition and/or growth. Conversely, forage fish such as seminole killifish may be more vulnerable to predation, possibly resulting in a short term reduction in population abundance. As in high water events, nutrients are released to the water column upon refill. The combination of available nutrients and a diverse plant community stimulates a robust food web that positively affects populations of fish and aquatic oriented wildlife.

Drawdowns have been used to mimic historical low water events within the Kissimmee Chain of Lakes since 1971. Effects of drawdowns include a reduction in invasive aquatic macrophyte biomass/monocultures by exposing and consolidating organic sediment and destroying the reproductive parts of plants (Cooke 1980), and expanding desirable littoral habitats (Holcomb and Wegener 1972) which provide foraging and nursery areas.

Drawdowns have had impacts to various fish populations. Increased recruitment among sportfish species have been documented (Allen and Tugend 2002; Hulon et al. 1999; Benton et al. 1994; Lantz et al. 1967); however, survivorship over time has varied. Additionally, abundance of individual fish species have varied in their responses to drawdowns (Moyer et al. 1996; Moyer et al. 1982; Williams et al. 1982; Wegener and Williams 1975). Increased growth for different age classes of sportfish have been documented (Allen and Tugend 2002; Hulon et al. 1997). However, similar growth over time (Allen et al. 2003) or even decreased growth has also been observed (Hulon et al. 1997). Positive trends in the fishery (i.e. creel) were usually observed following a drawdown, although individual species often responded differently (Moyer et al. 1996; Wegener and Williams 1975; Heman et al. 1969; Lantz et al. 1967).

Generally, positive but variable effects occur between species and among lakes over time. Even though the long-term influence of low water events and/or drawdowns can be variable, it is clear that many benefits to habitat and the fish community can be derived in the short-term and possibly long-term as well.

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Life History Requirements of Wading birds

Life History Requirements and Links to Habitat

Wading birds (waders) include a wide variety of species from the families Ardeidae (herons, egrets, and bitterns), Threskiornithidae (ibis and spoonbills), and Ciconiidae (storks and jabirus). The only federally listed species found in Florida is the wood stork (*Myceteria americana*) which is listed as Endangered. State-listed Species of Special Concern inhabiting freshwater wetlands in central Florida include the tricolored heron (*Egretta tricolor*), white ibis (*Eudocimus albus*), little blue heron (*Egretta caerulea*), and snowy egret (*Egretta thula*) (FWC 2003; FWC 2004).

Waders are dependent on wetlands throughout their life cycle for foraging and nesting. They are a diverse group with many species utilizing different water depths, consuming different prey, and nesting at different times. Their primary habitat is highly productive and somewhat open wetlands.

Most wading birds nest in colonies in flooded woody vegetation (willow, *Salix* sp.; buttonbush, *Cephalanthus occidentalis*; Brazilian pepper, *Schinus terebinthifolus*; guava, *Psidium guajava*; cypress, *Taxodium* sp.) or in upland sites on islands within lake sites. Nesting over water reduces predation by providing a water barrier to terrestrial predators or allowing alligators to move beneath the nest trees, thereby further dissuading predators (Rodgers 1987). The large colony that once nested on Lake Kissimmee until the lake was drawn down in 1996 nested primarily in guava and buttonbush (Bird Island) and willow (Rabbit Island) (Rodgers, pers. comm.). During years of high lake levels (>14.5 meters), wading birds nested in the flooded willow-buttonbush thickets of interior Lemon Point/Sturm Island. The occasionally active colony on Mackinson Island or Paradise Island of Lake Toho nested mostly in willow (Rodgers, pers. comm.).

Solitary and semi-colonial nesting species (least bittern, *Ixobrychus exilis*; green-backed heron, *Butorides virescens*) nest in flooded dense cattail (*Typha* sp.), bulrush (*Scirpus* sp.), or occasionally in *Ludwigia*. Colonies populated by a mixed-species assemblage of anhingas, cormorants, herons, egrets, and ibises nested at wooded sites. No data are available on minimum water depth beneath nest trees or minimum size of plant species for nesting in the KCOL. However, water depths of 25-30 cm at nest sites may be sufficient to dissuade terrestrial predators from accessing nest trees (Rodgers, pers. comm.). The limb structure is another important factor in determining suitability of trees as nest sites for wading birds.

There is considerable variation among the timing of nesting seasons for wading bird species and occasionally inter-year variation in the timing of nest initiation. The dates presented here are based on data from nests in similar latitude to the KCOL. Larger species (great blue heron, *Ardea herodias*; great egret, *Casmerodius albus*; anhinga, *Anhinga anhinga*) typically begin nesting earlier (January-February) than the smaller day herons (little blue heron; tri-colored heron ; snowy egret; cattle egret, *Bubulcus ibis*; March-April) within the same colony. In general, wading bird colonies remain active from as early as late December until at least August, sometimes later if the nesting season begins late.

Modal clutch size for all wading birds is 3 eggs, range 1-5 eggs, with minor inter-year and inter-lake variation (Rodgers, pers. comm.). Fledging success is generally variable among years and lakes, probably reflecting amount and distribution of prey. Based on data from other lakes, nest success (>1 young per nest) ranged from 55-88%. A study of Lake Okeechobee water levels and wading bird abundance suggests that numbers of foraging wading birds increased when moderately high winter lake levels were followed by a moderately steady, protracted (5-6 months) drawdown of lake levels beginning in December or January (David 1994).

Lake stage determines the upper and lower regions of the littoral zone used for foraging by wading birds. As their collective name implies, wading birds forage in shallow water (0-20 cm for smaller species, 5-35 cm for larger species) (Comiskey et al. 1998). Specific optimal depth is determined by the length of the legs of each species. Preferred feeding habitat consists of a mosaic of open water and emergent vegetation, dominated by *Eleocharis, Rhynchospora, Panicum, Nymphaea, and Pontederia*. No data are available on optimal stem densities, but percent coverage above 50% probably is sufficient to reduce foraging efficiency and access to aquatic prey (Rodgers, pers. comm.). Dense wooded (willow, buttonbush) areas and *Pontederia* and *Typha* regions are under utilized for foraging~~,~~ relative to their availability (Smith et al. 1995). Prey consists of invertebrates (insect larvae, crayfish), fish and amphibians which waders stalk in both open water and sparely vegetated regions of the littoral zone. Both shallow, open water areas and recently exposed lake bottom are used by ibis that forage on benthic fauna.

Impacts of Low and High Water

Impacts of Low Water

Extremely low lake levels provide access for terrestrial predators to wading bird nests or result in reduced nesting attempts. However, gradual reduction of lake levels during the breeding season has been shown to increase numbers of foraging wading birds at lakes with levees such as Lake Okeechobee (David 1994). Periodic low water levels also allow seed germination and thereby help maintain desirable habitat condition. The effects of water levels on wading bird nest productivity and foraging success may well vary from lake to lake depending on surrounding habitat types, location of colonies, lake bottom slopes, and other factors. Ongoing research such as the “Wading Bird Response to Water Patterns in the Northern and Central Everglades” project (http://www.sfwmd.gov/org/wrp/wrp_evg/projects/birds/bird_animation.html) may eventually provide a clearer picture of how best to manage water levels for waders.

Impacts of High Water

Prolonged, elevated water levels negatively affect wading birds in a variety of ways. First, their prey is dispersed, resulting in reduced prey density (Rodgers, pers. comm.). This can result in lower nest productivity if the parent birds cannot secure prey from other sources (if alternate sources are nearby, wading birds may not be affected). Second, high water levels can eventually weaken or kill aquatic woody vegetation, reducing or eliminating nest sites. Third, elevated water levels can reduce seed germination and over time alter foraging or nesting habitat. Alternatively, periodic high water events can flood new habitats, which can be very productive as foraging habitats.

Specific Recommendations

We recommend maintaining moderately high winter lake levels (>14.5m for Lake Kissimmee), followed by a moderate, steady, protracted (5-6 months) drawdown beginning in December or January. This schedule would be expected to maximize wading bird foraging habitat and nesting success.

Recommended future research

Additional research is needed to better determine optimal foraging habitat for wading birds in the KCOL. Specifically, what are optimal emergent vegetation stem densities for wading bird foraging? Can different lake levels in the KCOL be correlated to wading bird nesting success? Where are preferred wading bird foraging areas in the KCOL, and how do they change in response to changes in water level? The distribution of preferred wading bird foraging habitat on the KCOL should be mapped and monitored for changes before and after lake restoration activities.

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