Wood Stork Foraging Habitat Assessment Methodology **July 12, 2012**

The decline of the wood stork in the United States is primarily due to the loss of wetland habitats and the concomitant reduction in prey availability. To determine the effect of development actions on the wood stork in south Florida, the Service has chosen to assess the action's effect on wood stork foraging habitat. As such, the Service has developed a functional assessment known as the "Wood Stork Foraging Habitat Assessment Methodology" (Methodology), as described below. The Methodology can be used to estimate the biomass of wood stork forage provided per unit quantity of wetland habitat. The assessment can be applied to both wetlands being lost by a development project and the wetlands proposed as mitigation.

The Service has identified four parameters that can be used in the estimation of wood stork prey biomass:

1. Vegetation Density
2. Wetland Hydroperiod
3. Prey Size Suitability
4. Competition with other wading bird species for forage

Parameter 1 - Density of vegetation

As discussed previously, a wetland's suitability for wood stork foraging is partially dependent on its vegetation density. Coulter and Bryan (1993) found that wood storks prefer to forage in ponds and marshes with little or no canopy. Wood storks have been observed foraging in forested wetlands (*e.g.,* swamps, mesic woodlands etc.), but prefer open areas within these habitat types (Coulter and Bryan 1993; P.C. Frederick, University of Florida, personal communication 2006; J.A. Rodgers, FWC, personal communication 2006). Coulter and Bryan (1993) suggested that wetlands with open canopies may be more readily detected by wood storks and are easier to land at than at closed-canopy sites. Wetlands with sparse canopies also allow wood storks to take flight more quickly to avoid predators.

The presence of invasive exotic plants may also affect wood stork foraging. Melaleuca (*Melaleuca quinqueneriva*) is an exotic tree species that has become established in south Florida's wetlands. Melalueca produces dense stands that may limit a site's accessibility to foraging by wading birds including the wood stork. O'Hare and Dalrymple (1997) investigated the effects of melalueca infestation on wetland-dependent birds in south Florida wetlands. A moderate level of melalueca infestation was found to have little effect on the production of some prey species use by the wood stork (*i.e.*, amphibians and reptiles) as long as the wetland's critical abiotic factors (*e.g.,* hydrology) were not significantly impaired (O'Hare and Dalrymple 1997). However, fish abundance was found to decrease in closed canopy melalueca forests. Wood storks will forage in melaleuca-dominated wetlands when the distribution of trees is sparse or non-continuous (*i.e.,* areas of broken stands due to blow-downs). However, wood storks generally will not forage in melaleuca where the stem density is high and the canopy closed (P.C. Frederick, University of Florida, personal communication 2006). The limiting factor to wood stork foraging within melalueca-dominated wetlands appears to be the restriction of access to the area resulting from the presence of the vegetation.

Parameter 1 - Foraging suitability value (Vegetation Density)

To determine how the presence of invasive exotic vegetation may affect wood stork foraging, we developed foraging suitability indices for wetlands (as described below) using data from O'Hare and Dalrymple (1997). O'Hare and Dalrymple (1997) identified five vegetation classes based on coverage of melalueca (Table WSM1):

Table WSM1. Classes of Melalueca Coverage (from O'Hare and Dalrymple 1997).

75-100 percent mature dense melaleuca coverage (DMM)
75-100 percent sapling dense melaleuca coverage (DMS or SDM)
50-75 percent melaleuca coverage (P75)
0-50 percent melaleuca coverage (P50)
0-10 percent melaleuca coverage (Marsh [MAR])

The number of wetland-dependent bird species and individuals observed per cover type by O'Hare and Dalrymple (1997) are listed in columns 2 and 3 in Table WSM2.

Table WSM2. Foraging suitability indices for wetland-dependent birds species.

Cover type	No. of species (S)	No. of individuals (I)	S*I	Foraging suitability
DMM	1	2	2	0.001
DMS	4	10	40	0.025
P75	10	59	590	0.372
P50	11	92	1,012	0.639
MAR	12	132	1,584	1.000

The foraging suitability index for wetlands dependent birds is calculated for each cover type from O'Hare and Dalrymple (1997) (Table WSM2) by multiplying the number of species observed (S) by the number of individuals observed (I). The product (S*I) is then divided by the product of the number of species for MAR and the number of individuals for MAR (12 x 132 = 1,584) observed by O'Hare and Dalrymple (1997). Based on the calculations listed above, we developed foraging suitability indices for wetlands used by wood storks based on the coverage of exotic plants (Table WSM3). The Service chose 0.03 (the foraging suitability index for the DMS cover type, rounded up from 0.025) to define foraging suitability for exotic plant coverage ranging from 76 percent to 100 percent.

Table WSM3. Wood Stork Foraging Suitability Indices.

Exotic Plants (percent coverage)	Foraging Suitability Index
0 to 25	1.00
26 to 50	0.64 (rounded up from 0.639)
51 to 75	0.37 (rounded down from 0.372)
76 to 100	0.03 (rounded up from 0.025)

Parameter 2 – Wetland Hydroperiod

Hydroperiod: The hydroperiod of a wetland can affect the density of wood stork prey species. For example, studies of Everglades fish populations using a variety of quantitative sampling techniques (pull traps, throw traps, block nets) have shown that the density of small forage fish increases with hydroperiod. Marshes inundated for less than 120 days per year average ± 4 fish/meter $(m)^2$, and marshes inundated for more than 340 days per year average ± 25 fish/m^2 (Loftus and Eklund 1994; Trexler et al. 2002).

Kushlan (1990) described short hydroperiod wetlands as wetlands inundated from 0 to 180 days per year, intermediate hydroperiod wetlands as wetlands inundated from 180 to 270 days per year, and long hydroperiod wetlands as wetlands inundated from 270 to 360 days per year. However, Trexler et al. (2002) defined short hydroperiod wetlands as wetlands with less than 300 days per year inundation. For the purposes of our Methodology, the Service defines wetlands inundated from 0 to 180 days per year as "short hydroperiod" wetlands and wetlands inundated from 180 to 360 days per year as "long hydroperiod" wetlands. In addition, we have adopted the seven wetland hydroperiod classes for wetlands in south Florida used by the SFWMD in their evaluation of various restoration projects throughout the Everglades Protection Area (Table WSM4).

Table WSM4. SFWMD's hydroperiod classes for Everglades Protection Area.

Hydroperiod Class	Number of days inundated
1	0-60
2	60-120
3	120-180
4	180-240
5	240-300
6	300-330
7	330-365

The Service estimated the fish biomass available to the wood stork for each of the SFWMD's hydroperiod classes listed in Table WSM4 as follows. First, we took estimates of fish density (number of fish/ m^2) for the various hydroperiod classes presented in Trexler et al. (2002) (Table WSM5). Trexler et al. (2002) derived these density estimates from throw trap sampling of wetland sites in the Everglades, and the estimates were presented as the square root of the number of fish/m^2 for each of six hydroperiod classes. It is important to note that Trexler et al. (2002) used six hydroperiod classes to characterize the length of inundation during the year compared to the seven hydroperiod classed employed by the SFWMD and used by the Service in our Methodology (Table WSM4). The fish density estimates presented Trexler et al. 2002, increase with hydroperiod class, and this trend has been noted by other investigators (Turner et al. 1999, Turner and Trexler 1997, Carlson and Duever 1979).

Table WSM5. Fish densities per hydroperiod from Trexler et al. (2002).

Hydroperiod class	Days inundated	Fish Density(fish/m^2)*
Class 1	0-120	2.0
Class 2	120-180	3.0
Class 3	180-240	4.0
Class 4	240-300	4.5
Class 5	300-330	4.8
Class 6	330-365	5.0

*As presented, these densities are square root transformed, as described in Trexler et al 2002.

For our assessment, we transformed the fish density data provided by Trexler et al. 2002 to obtain fish density values for each of seven hydroperiods defined by the SFWMD. We obtained a fish density value of 2 fish/m^2 for the SFWMD's Class 1 hydroperiod (0 to 60 days inundated; Table WSM6) by extrapolating Trexler et al.'s Class 1 hydroperiod fish density value of 2.0 fish/m^2 for 0 to 120 days inundated to 1.0 fish/m.^{2} and doubling this value. To calculate fish density values for the remaining SFWMD hydroperiods (Classes 2 through 7), the fish density values for hydroperiod classes 1 through 6 presented by Trexler et al. 2002 (Table WSM5) were squared. Fish density values for each of the seven SFWMD hydroperiod classes are as presented in Table WSM6.

Table WSM6. Extrapolated values of fish density per each SFWMD hydroperiod.

Hydroperiod class	Days inundated	Fish density
Class 1	0-60	2 fish/m^2
Class 2	60-120	4 fish/m^2
Class 3	120-180	9 fish/m^2
Class 4	180-240	16 fish/m^2
Class 5	240-300	20 fish/m^2
Class 6	300-330	23 fish/m^2
Class 7	330-365	25 fish/m^2

The Service is aware the throw-trap method used by Trexler et al. (2002) generally only captures fish 8 centimeters (cm) (3.15 inches [in]) or less in total length. However, the Service believes the data provide a good approximation of the fish sizes preferred by wood storks. We note Ogden et al (1976) found wood storks generally consume fish ranging in total length from 1.5 cm (0.59 in) to 9 cm (3.54 in), and Kushlan et. al. (1975) reported wood storks feed primarily on fish from 6 cm (2.36 in) to 8 cm (3.15 in) total length. The Service is aware wood storks will occasionally forage on fish larger than 8cm total length, and we acknowledge this size class of fish is not completely captured by our methodology. However, we note only a small proportion of the wood stork's diet consists of fish greater than 8 cm total length. As such, we do not believe our assessment of wood stork foraging biomass is significantly flawed.

The transformed estimates of fish density listed in Table WSM6 are now used to estimate fish biomass for each of the seven hydroperiods. For our assessment, we considered class 7 hydroperiod wetlands with a density of 25 fish/m^2 to have a mean annual biomass of

6.5 grams /m^2 (wet mass). This estimate of mean annual biomass was based on studies conducted by Turner et al. (1999), Trexler et al. (2002), and Carlson and Duever (1979) in Everglades National Park and WCA 3A. In these studies, the mean biomass (standing stock) of fish from Class 5 and 6 hydroperiod wetlands ranged from 5.5 to 6.5 grams/m^2 (wet mass). These data were originally calculated as g/m^2 dry mass and converted to g/m^2 wet mass following the procedures referenced in Kushlan et al (1986) and also referenced in Turner et al (1999). The fish density data provided in Turner et al. (1999) included both data from samples representing fish 8 cm or smaller and fish larger than 8 cm (3.15 in) and included summaries of data presented in Turner and Trexler (1997), Carlson and Duever (1979), and Loftus and Eklund (1994). These data sets also applied a 0.6 g/m^2 (dry mass) correction estimate for fish greater than 8 cm (3.15 in) based on Turner et al's (1999) block-net rotenone samples.

We estimated the biomass for the SFWMD hydroperiod classes 1 through 6 based on the fish density of 25 fish/m^2 and the biomass of 6.5 grams/m^2 wet mass derived for the Class 7 hydroperiod described above. First, we calculated a mean biomass per fish value of 0.26 grams/m^2 wet mass by dividing 6.5 grams/m^2 wet mass by 25 fish/m^2. We then multiplied the mean biomass per fish value of 0.26 grams/m^2 wet mass by the fish density values for hydroperiod classes 1 through 6. For example, the biomass of fish provided by the Class 3 hydroperiod is 2.3 grams/m^2 (9*0.26 = 2.3). The calculated values of fish biomass are presented in Table WSM7.

Table WSM7. Estimated mean annual fish biomass for SFWMD's hydroperiods.

Hydroperiod class	Days inundated	Mean annual fish biomass
Class 1	0-60	0.5 gram/m^2
Class 2	60-120	1.0 gram/m^2
Class 3	120-180	2.3 grams/m^2
Class 4	180-240	4.2 grams/m^2
Class 5	240-300	5.2 grams/m^2
Class 6	300-330	6.0 grams/m^2
Class 7	330-365	6.5 grams/m^2

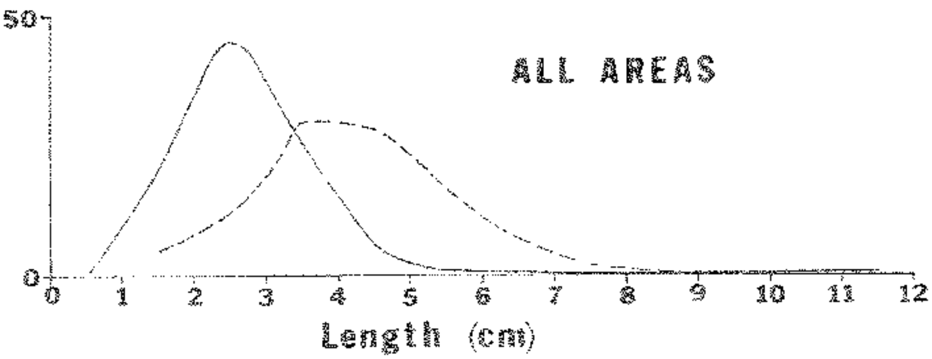
Parameter 3 – Prey Size Suitability

Wood storks are highly selective in their feeding habits. Ogden et al. (1976) reported that five species of fish comprised over 85 percent of the number and 84 percent of the biomass of over 3,000 prey items collected from adult and nestling wood storks (Table WSM8). These species were also observed to be consumed by wood storks in greater proportion than smaller and more abundant fish species [*e.g.*, mosquito fish (*Gambusia affinis*), least killifish (*Heterandria formosa*), and bluefin killifish (*Lucania goodei*)]. This may be the result of the small body size of these species not eliciting a bill-snapping reflex by wood storks (Coulter et al. 1999).

Table WSM8. Primary fish species consumed by wood storks from Ogden et al. (1976).

Common name	Scientific name	Percent individuals	Percent biomass
Sunfishes	*Centrarchidae* spp.	14	44
Yellow bullhead	*Italurus natalis*	2	12
Marsh killifish	*Fundulus confluentus*	18	11
Flagfish	*Jordenella floridae*	32	7
Sailfin molly	*Poecilia latipinna*	20	11

The following figure from Ogden et al. (1976) compares the frequency (expressed as percent, 0 to 50) of the fish size available to wood storks (solid line) and the frequency of fish size consumed by wood storks (dashed line).



The area under the dashed line represents the size of fish most likely consumed by wood storks (1.5 to 9.0 cm in total length). The Service has adopted this range of fish sizes as those most likely to be consumed by the wood stork and we will use this size range in our assessment of wood stork forage (see discussion below). As discussed above, the throw-trap method used by Trexler et al. (2002) generally only captures fish 8 cm or less in total length, and wood storks occasionally comsume fish larger than 8cm in total length. However, the Service believes the data from Trexler et al. (2002) provide a good approximation of the fish sizes preferred by wood storks.

The next element of our wood stork Methodology is the wood stork suitable prey base (biomass per hydroperiod). The wood stork suitability prey base is comprised of two components: (1) the amount of biomass per hydroperiod class within the range of fish sizes likely to be consumed by wood storks and (2) the likelihood that this prey base is actually consumed by the wood stork.

To estimate the fraction of the available fish biomass within the size range of fish likely to be consumed by wood storks (1.5 to 9.0 cm), the Service used the following approach. We noted that Kushlan et al. (1986) listed the mean biomass of the warmouth (*Lepomis gulosus*) as 36.76 g (rounded to 36.8 g in Appendix WSM-A [see page 12]). In Trexler et al. (2002), the warmouth accounts for about 0.048 percent (18/37,715=0.000477) of the total number of fish collected during the study (Appendix WSM-A). We then multiplied the mean biomass of 36.76 g of the warmouth reported by Kushlan et al. (1986) by the percent occurrence value of 0.048 percent provided by Trexler et al. 2002 to calculate an adjusted mean biomass of 1.75 g (36.76 g * 0.048 = 1.75 g). The mean biomass of the warmouth (1.75 g) accounts for 6.57 percent (1.75/26.715 = 0.0657) of the estimated average biomass (26.715 g) of Trexler et al.'s (2002) samples. Using the Service's estimate of mean annual biomass for class 7 hydroperiod wetlands of 6.5 g/m^2, the warmouth biomass for class 7 hydroperiod wetlands would be 0.427 g/m^2 (6.5 g/m^2 x 0.0657 = 0.427 g/m^2).

However, the Service noted the size frequency distribution (assumed normal) of warmouth from Kushlan et al. (1986) indicate that 48 percent of warmouth sampled were greater than 9 cm total length and 0.6 percent were less than 1.5 cm total length. As such, 48.6 percent of warmouth were outside of the size range (1.5 cm to 9 cm total length) of fish most likely consumed by the wood stork. The mean annual biomass for warmouth for class 7 hydroperiod wetlands in the size range likely consumed by the wood stork is calculated as 0.208 g/m^2 [0.427*(0.48+0.006)]=0.2075 g/m^2 (rounded to 0.208). Using this approach for all fish species collected by Trexler et al. 2002 (Appendix WSM-A) for class 7 hydroperiod wetlands, the Service estimates that only 3.685 g/m^2 of the 6.5 g/m^2 mean annual fish biomass consists of fish within the size range likely consumed by wood storks (about 57 percent [3.685/6.5*100=56.7] of the total mean annual fish biomass available).

The Service also used data in Ogden et al 1976 (Appendix WSM-A) to estimate the available mean annual fish biomass for fish within the size range likely consumed by wood storks for class 7 hydroperiod wetlands. We calculated that 2.97 g/m^2 of the 6.5 g/m^2 mean annual fish biomass for a class 7 hydroperiod wetland (about 45.7 percent) consists of fish within the size range likely to be consumed by wood storks.

Finally, we adjusted the values of estimated mean annual fish biomass for each of the SFWMD's hydroperiods (Table WSM7) to reflect the size of fish most likely consumed by woods storks. This was accomplished by adding the biomass value of 3.685 g/m^2 (derived from data in Kushlan et al. 1986 and Trexler et al. 2002; Appendix WSM-A) to the biomass value of 2.97 g/m^2 (derived from data in Ogden et al 1976 2002; Appendix WSM-A) and dividing the sum of 6.665 g/m^2 by to obtain a mean value of 3.33 g/m^2 for class 7 hydroperiod wetlands. The Service notes that the mean biomass value of 3.33 g/m^2 s for class 7 hydroperiod wetlands comprises 51 percent of the mean annual biomass estimate of 6.5 g/m^2 for class 7 hydroperiod wetlands listed in Table WSM7 (3.33 g/m^2/6.5 g/m^2 = 0.51 or 51 percent). Therefore, we multiplied each value of mean annual fish biomass listed in Table WSM7 to calculate values of mean annual fish biomass per hydroperiod adjusted for the size range of fish (1 to 9 cm total length) most likely to be consumed by wood storks (*i.e.*, the wood stork suitable prey base) (Table WSM9).

Table WSM9. Estimates of suitable fish biomass per hydroperiod.

Hydroperiod class	Days inundated	Fish biomass
Class 1	0-60	0.26 gram/m^2
Class 2	60-120	0.52 gram/m^2
Class 3	120-180	1.196 grams/m^2
Class 4	180-240	2.184 grams/m^2
Class 5	240-300	2.704 grams/m^2
Class 6	300-330	3.12 grams/m^2
Class 7	330-365	3.38 grams/m^2

Crayfish Biomass

Although the diet of the wood stork is made up primarily of fish, wood storks are known to forage on crayfish (*Procambarus* spp.) (J. Lauritsen, Audubon Corkscrew Swamp Sanctuary, personal communication 2007, 2009; Depkin et al. 1992; Bryan and Gariboldi 1998; Kahl 1964). Depkin et al. (1992) report that crayfish make up 1 percent of the biomass and 1.9 percent of the prey items observed for wood storks from east-central Georgia and also noted the presence of crayfish in the diets of wood storks (fish represented 92 percent of all individual prey items and 93 percent of the total biomass). Lauritsen (Audubon Corkscrew Swamp Sanctuary, personal communication 2007, 2009) suggests crayfish may be an important source of food for wood storks. The importance of crayfish in the wood stork's diet in unclear. Nonetheless, the Service has decided to assess crayfish biomass as part of our estimate of biomass production per hydroperiod.

The presence of melalueca in wetlands does not seem to affect the use of these habitats by crayfish. O'Hare and Dalrymple (1997) found that crayfish are randomly distributed among cover types and melaleuca coverage did not largely affect dispersion patterns. Lauritsen (Corkscrew Swamp Sanctuary 2007, 2009) noted crayfish occur in wetlands with dense melaleuca and migrate to more open areas as water levels fall during the dry season. Hendrix and Loftus (2000) noted that *P. alleni* typically burrow during the dry season, a behavior which provides persistence during droughts, and *P. fallax* was typically found in long hydroperiod wetlands.

Acosta and Perry (2002) assessed the biomass of the *P. alleni* from seasonal wetlands of various hydroperiods within the Florida Everglades. However, Acosta and Perry (2002) defined wetland hydroperiods in terms of months of inundation. Therefore, the Service converted the hydroperiod class used in Acosta and Perry (2002) from months of inundation to days of inundation for use in our Methodology. Acosta and Perry (2002) only provided crayfish density and biomass estimates for wetlands of hydroperiod class 2, 4, and 5, and the converted values are 0.10 gram/m^2, 0.15 gram/m^2, and 0.23 gram/m^2, respectively (Table WSM10). Acosta and Perry (2002) noted that long hydroperiod wetlands typically had densities of crayfish two times greater than medium hydroperiod wetlands and five times greater than short hydroperiod wetlands. Therefore, we estimated the crayfish biomass for hydroperiod Class 3 wetlands by adding the crayfish biomass estimate for hydroperiod class 2 wetlands (0.10 gram/m^2) to the crayfish biomass estimate for hydroperiod class 4 wetlands (0.15 gram/m^2) and divided the sum (0.25 gram/m^2) by 2 to obtain a value of 0.125 gram/m^2 (rounded to 0.13 gram/m^2 in Table WSM10). The Service estimated the mean annual crayfish biomass for Class 1 hydroperiod wetlands based on Acosta and Perry's (2002) comment that long hydroperiod wetlands typically had densities five times greater than short hydroperiod wetlands. Therefore, the Service used Acosta and Perry's (2002) average long hydroperiod value for crayfish biomass of 0.229 grams/m^2 and divided this value by 5 to calculate a value of 0.05 gram/m^2 for Class 1 hydroperiod wetlands (0.229/5=0.045). We estimated the crayfish biomass value for the Class 7 hydroperiod wetlands based on the maximum density recorded in Acosta and Perry's (2002) study (0.248 gram/m^2, rounded to 0.25 gram/m^2 in Table WSM10). Finally, we estimated the crayfish biomass for class 6 hydroperiod wetlands by adding the crayfish biomass estimate for hydroperiod class 5 wetlands (0.23 gram/m^2) to the crayfish biomass estimate for hydroperiod class 7 (0.25 gram/m^2) and divided the (0.48 gram/m^2) by 2 to obtain a value of 0.24 gram/m^2 (Table WSM10).

To estimate the total forage biomass available to the wood stork for each wetland hydroperiod class (Table WSM9), we added the value of mean annual crayfish biomass derived from Acosta and Perry 2002 to the value of mean annual biomass estimated for fish (Table WSM10).

Table WSM10. Estimates of suitable fish biomass and crayfish biomass per hydroperiod.

Hydroperiod class	Fish biomass	Crayfish biomass	Total biomass	Percent change
Class 1	0.26 gram/m^2	0.05 gram/m^2	0.31 gram/m^2	19.2
Class 2	0.52 gram/m^2	0.10 gram/m^2	0.62 gram/m^2	19.2
Class 3	1.19 grams/m^2	0.13 gram/m^2	1.32 grams/m^2	10.5
Class 4	2.18 grams/m^2	0.15 gram/m^2	2.34 grams/m^2	7.0
Class 5	2.70 grams/m^2	0.23 gram/m^2	2.93 grams/m^2	8.4
Class 6	3.12 grams/m^2	0.24 gram/m^2	3.36 grams/m^2	7.7
Class 7	3.38 grams/m^2	0.25 gram/m^2	3.63 grams/m^2	7.4

Parameter 4 – Competition with other wading bird species for forage

The computer simulations of wood stork colony population size by Fleming et al. (1994) assumed that only 10 percent of the wood stork forage prey base is available to be consumed by wood storks. This reduction in prey availability was attributed to water level of the foraging habitat, and in part to the effects of competition with other wading bird species. Fleming et al. (1994) did not specify the magnitude of each effect, but the Service believes it is likely competition with other wading bird species limits the availability of prey to wood storks. As such, the Service has included competition with other wading bird species for forage as a parameter in our assessment of wood stork forage biomass.

The Service has chosen to assess the effects of competition of other wading bird species on wood stork biomass availability as follows. We have adopted the assumption made by Fleming et al. (1994) that only 10 percent of the potential forage at a wetland site is available to wood storks for foraging. This figure represents a 90 percent reduction of total forage biomass actually available to wood storks at a wetland site. The Service considers competition for forage with other wading bird species, as well as the 3 factors described above (vegetation density, wetland hydroperiod, and prey size) as all contributing equally to the reduction in forage availability. Consequently, we find that each factor comprises 0.225 or 22.5 percent of the total 90 percent reduction in forage availability (4 x 22.5 = 90 percent). As discussed above, our assessment has already accounted for the effects of vegetation density, wetland hydroperiod, and prey size. To adjust the estimates of total biomass per hydroperiod presented in Table WSM10 for the effects of competition with other wading bird species, we have established a competition adjustment factor of 0.325. This factor was calculated by subtracting 0.675 (the sum of reduction in forage availability due to vegetation density, wetland hydroperiod, and prey size [0.225 + 0.225 + 0.225 = 0.675) from 1 (this number represents 100 percent of the total forage biomass present at a wetland site) (1 – 0.675 = 0.325). Table WSM11 presents estimates of total forage biomass adjusted for competition.

Table WSM 11. Estimates of total biomass of fish and crayfish per hydroperiod adjusted for the effect of competition with other wading birds.

Hydroperiod class	Total Fish and Crayfish Biomass	Competition Factor	Adjusted Total biomass (Total Fish and Crayfish Biomass x Competition Factor)
Class 1	0.31 gram/m^2	0.325	0.1008 gram/m^2
Class 2	0.62 gram/m^2	0.325	0.2015 gram/m^2
Class 3	1.32 grams/m^2	0.325	0.4290 grams/m^2
Class 4	2.34 grams/m^2	0.325	0.7605 grams/m^2
Class 5	2.93 grams/m^2	0.325	0.9523 grams/m^2
Class 6	3.36 grams/m^2	0.325	1.0920 grams/m^2
Class 7	3.63 grams/m^2	0.325	1.1798 grams/m^2

Summary of the factors affecting vulnerability of wetland habitats to wood stork foraging in the action area

Through the above discussions, we have identified that there are essentially four parameters in assessing wood stork foraging habitat.

1. The density of vegetation within habitats suitable for wood stork foraging;

2. The hydroperiod of the wetland, including two subcomponents: (a) the fish density per hydroperiod (number of fish), and (b) the fish biomass per hydroperiod (g/m^2);

3. The size of prey size; and

4. Competition with other wading bird species

All four of these parameters can be used to calculate an estimate of the forage biomass available to wood storks in a wetland. As such, the Methodology can be applied to both wetlands being lost by a development project and the wetlands proposed as mitigation to assess the effect of an action on wood stork foraging. The following example illustrates the use of the Methodology:

> A development project results in the loss of 50 acres of wetland (25 acres of Class 3 hydroperiod and 25 acres of Class 4 hydroperiod), each containing 10 percent cover of melaleuca. The forage biomass of a each wetland is calculated by multiplying the number of acres of wetlands impacted by 4,047 m^2 (to convert acres to m^2) by the amount of actual biomass consumed by the wood stork (Table WSM11) and the exotic foraging suitability index (Table WSM3). The Service's Methodology considers the portion of the wetland covered by exotic vegetation (*i.e.*, the 10 percent melalueca in this

example) as 100 percent suitable to wood storks. To adjust for habitat availability and the wood stork competition factor, the value of forage biomass derived in Table WSM11 is multiplied by 1.0 (*i.e.*, habitat is 100 percent suitable for wood storks). The product is divided by 1,000 grams to convert the forage biomass value calculated in grams to kilograms.

The 25 acres of class 3 hydroperiod wetlands provide 43.4 kg of biomass forage [(25 acres x 4,047 m^2 /acre x 0.4290 g/m^2 (Table WSM11) x 1.0 (Table WSM3))/1,000 grams =43.4 kg)], and the 25 acres of class 4 hydroperiod wetlands provide 76.94 kg of biomass forage [(25 acres x 4,047 m^2 /acre x 0.7605 g/m^2 (Table WSM11) x 1.0 (Table WSM3) x 1.0)/1,000 grams =76.94 kg)]. The total forage biomass (fish and crayfish) lost due to the action is 120.34 kg (43.4 kg from class 3 hydroperiod wetlands + 76.94 kg from class 4 hydroperiod wetlands), and this value represents the loss of 0.61 nest based on Kahl's (1964) estimate that 201 kg of forage was needed for a successful wood stork nest.

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Appendix WSM-A.

Data from Kushlan et al. (1986), Ogden et al. 1986, and Trexler et al. (2002) used by the Service to estimate the fraction of the available fish biomass within the size range of fish that may be consumed by wood storks.

		Kushlan et al. (1986)				Ogden et al. (1976)		Everglades - Trexler et al. (2002)				
Species	Common name	Mean Mass (g)	Proportion of fish < 15mm	Proportion of fish > 90mm	Proportion within 15-90 mm wood stork preference	% items consumed by stork	% biomass consumed by stork	Total collected	% of total collected	Mean mass based on % collected	Mass within 6 g/m2	Mass within stork prey size
Osteichtheyes												
Amia calva	Bowfin	1307.3	0.000	0.997	0.002	0.1	0.1		0.000	0.000	0.000	0.000
Lepisosterus platyrhincus	gar	182.5	0.012	0.948	0.039	0.2	2.8	1	0.003	0.484	0.109	0.004
Elops saurus	lady fish	346.7	0.000	1.000	0.000				0.000	0.000	0.000	0.000
Notemigonus crysoleucas	golden shiner	2.5	0.086	0.028	0.885	0.1	0.2		0.000	0.000	0.000	0.000
Notropis petersoni	coastal shiner	0.3	0.029	0.000	0.971			60	0.159	0.046	0.010	0.010
Notropis maculatus	taillight shiner					0.2	0.1	1	0.003	0.000	0.000	0.000
Erimuzon sucetta	Lake cubsucker	20.5	0.300	0.211	0.489				0.000	0.000	0.000	0.000
Ictalurus natalis	yellow bullhead catfish	29.0	0.063	0.438	0.499	1.7	11.8	29	0.077	2.228	0.500	0.250
Ameiurus nebulosus	brown bullhead catfish								0.000	0.000	0.000	0.000
Noturus gyrinus	tadpole madtom	1.4	0.052	0.000	0.948	0.2	0.1	8	0.021	0.029	0.007	0.006
Clarias batrachus	walking catfish	40.5	0.016	0.796	0.188			4	0.011	0.429	0.096	0.018
Bagre marinus	gafftopsail catfish	464.4	0.000	0.997	0.003				0.000	0.000	0.000	0.000
Opsanus beta	gulf toadfish	14.9	0.001	0.339	0.660				0.000	0.000	0.000	0.000
Strongylura notata	redfin needlefish	3.9	0.034	0.669	0.297				0.000	0.000	0.000	0.000
Adinia xenica	diamond killfish	0.7	0.002	0.000	0.998				0.000	0.000	0.000	0.000
Cyprinidon variegatus	sheepshead minnow	0.3	0.278	0.000	0.722	4.1	2.7	41	0.109	0.035	0.008	0.006
Floridichthylys carpio	goldspotted killfish	1.1	0.033	0.000	0.967				0.000	0.000	0.000	0.000
Fundulus chrysotus	golden topminnow	0.4	0.273	0.000	0.727	1.3	0.8	1844	4.889	1.750	0.393	0.286
Fundulus confluentus	marsh killifish	0.5	0.188	0.000	0.812	18.0	10.7	87	0.231	0.120	0.027	0.022
Fundulus grandis	gulf killfish	9.9	0.001	0.118	0.881				0.000	0.000	0.000	0.000
Fundulus seminolis	seminole killifish	5.8	0.000	0.110	0.890	0.7	3.1	1	0.003	0.016	0.003	0.003
Jordanella floridae	flagfish	0.3	0.260	0.000	0.740	32.0	7.0	1783	4.728	1.480	0.332	0.246
Lucania goodei	bluefin killifish	0.1	0.280	0.000	0.720	0.1	0.1	8391	22.248	2.759	0.620	0.446
Lucania parva	rainwater killifish	0.2	0.150	0.000	0.850	0.3	0.1	1	0.003	0.001	0.000	0.000
Gambusia affinus	mosquitofish	0.1	0.464	0.000	0.536	6.3	0.5	9825	26.051	2.214	0.497	0.266
Heterandria formosa	least killifish	0.0	0.917	0.000	0.083	0.5	0.1	12713	33.708	1.315	0.295	0.025
Poecilia latipinna	sailfin molly	0.2	0.292	0.000	0.708	19.8	10.6	1699	4.505	1.081	0.243	0.172
Labidesthes sicculus	brook silverside	0.5	0.002	0.000	0.998	0.1	0.1	5	0.013	0.007	0.002	0.002
Menidia beryllina	tidewater silverside	0.8	0.000	0.000	1.000	0.1	0.1		0.000	0.000	0.000	0.000
Elassoma evergladei	everglades pygmy sunfish	0.2	0.250	0.000	0.750			487	1.291	0.200	0.045	0.034
Enneacanthus gloriosus	bluespotted sunfish	0.5	0.155	0.000	0.845	0.8	0.9	238	0.631	0.321	0.072	0.061
Lepomis gulosus	warmouth	36.8	0.006	0.484	0.510	4.8	27.2	18	0.048	1.754	0.394	0.201
Lepomis macrochirus	bluegill	21.2	0.047	0.283	0.670	0.3	0.7	6	0.016	0.337	0.076	0.051
Lepomis marginatus	dollar sunfish	2.1	0.046	0.000	0.954			14	0.037	0.077	0.017	0.016
Lepomis microlophus	redear sunfish	30.8	0.052	0.362	0.586	2.3	5.4	55	0.146	4.490	1.008	0.591
Lepomis punctatus	spotted sunfish	7.0	0.182	0.030	0.787	2.8	8.7	197	0.522	3.661	0.822	0.647
Lepomis	unidentified sunfish	12.6	0.137	0.134	0.729	2.5	1.0	16	0.042	0.534	0.120	0.087
Sunfish	unidentified sunfish	9.8	0.175	0.070	0.754	2.5	1.0		0.000	0.000	0.000	0.000
Micropterus salmoides	largemouth bass	104.0	0.007	0.855	0.138	0.3	4.4	4	0.011	1.103	0.248	0.034
Etheostoma fusiforme	swamp darter	0.4	0.002	0.000	0.998			2	0.005	0.002	0.001	0.001
Astronotus ocellatus	oscar								0.000	0.000	0.000	0.000
Hemichromis bimaculatus	jewelfish	4.2	0.092	0.000	0.908				0.000	0.000	0.000	0.000
Spilotum nicaraguense	Nicaraguan cichlid								0.000	0.000	0.000	0.000
Eucinostomus gula	jenny mojarra	2.9	0.000	0.000	1.000				0.000	0.000	0.000	0.000
Haemulon plumieri	white grunt	6.2	0.000	0.011	0.988				0.000	0.000	0.000	0.000
Lagodon rhomboides	pinfish	7.1	0.001	0.039	0.960				0.000	0.000	0.000	0.000
Bairdiella chrysoura	silver perch	7.1	0.000	0.047	0.953				0.000	0.000	0.000	0.000
Cichlasoma bimaculatum	black acara	13.0	0.000	0.005	0.995			7	0.019	0.242	0.054	0.054
Cichlasoma urophthalmus	mayan cichlid							21	0.056	0.000	0.000	0.000
Mugil curema	white mullet					0.1	0.8		0.000	0.000	0.000	0.000
Rivulus marmoratus	rivulus					0.1	0.1		0.000	0.000	0.000	0.000
Esox niger	chain pickerel					0.1	0.1	5	0.013	0.000	0.000	0.000
Erimyzon sucetta	lake chubsucker							145	0.384	0.000	0.000	0.000
Belonesox belizanus	pike killifish							3	0.008	0.000	0.000	0.000
Tilapia mariae	spotted tilapia							4	0.011	0.000	0.000	0.000
Total								**37715**	**100.000**	**26.715**	**6.000**	**3.539**

*Shaded estimate of average mass from length-weight relationship given for species on www.fishbase.org with average length assumed to be 5 cm (FLMNH). The proportion of fish length less than 1.5 cm was set to be the average of all sunfish.