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Amphibian and Reptile Diversity of Alligator River National Wildlife Refuge, North Carolina*

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Abstract - In the past century, habitat alteration and fragmentation have increased dramatically, which increases the need for improving our understanding of how species and biological communities react to these modifications. A national strategy on biological diversity has focused attention on how these habitat modifications affect species, especially herpetofauna (i.e., changes in species richness, community evenness and similarity, and dominant/rare species). As part of this strategy, we surveyed Alligator River National Wildlife Refuge (ARNWR), a coastal, mixed second-growth forested swamp (MFS) and pocosin wetland (PW), in North Carolina for amphibians and reptiles from September 2000 to August 2001. We randomly selected three sites (3 x 3 km) in two major habitat types (MFS, PW) and completed random surveys and trapping using transects, quadrats, nighttime aural road surveys, drift fences, canal transects, coverboards, incidental captures, and evening road surveys. We also collected herpetofauna opportunistically throughout the refuge to establish an updated species list. For analysis, we used Shannon-Weiner species diversity (H'); evenness (J'); species richness and species detectability (COMDYN4); and community percent similarity index to determine herpetofaunal community differences. We estimated 39 species in MFS and 32 species in PW ($P < 0.10$). Species detectability was similar between habitats (0.84 to 0.86). More reptilian species (+31%) inhabited MFS than PW but estimated amphibian species richness was identical (17 spp.). H' was higher ($P < 0.0001$) for PW (2.6680) than for MFS (2.1535) because of lower J' in the latter (0.6214 vs. 0.8010). Dominance of three *Rana* species caused lower J' and H' in MFS. Similarity between the communities was 56.6%; we estimated 22-24 species in common for each habitat (95% CI = 18 to 31 spp.). We verified 49 of the 52 herpetofaunal species on the refuge that were known to exist in the area. Restoration of natural water flows may affect herpetofaunal diversity, which may be monitored during a restoration project. Currently, the refuge retains historical levels of herpetofaunal diversity for the region.

Fig. 1. Mixed Forest Swamp (MFS, left) and Pocosin Wetland (PW, right).

OBJECTIVES: to determine the absence or presence of herpetofauna in the two major habitat types (MFS and PW) of ARNWR; to determine the community composition (species diversity, evenness, species richness, community similarity) for each major habitat; and to provide a herpetofaunal species list for the refuge.

STUDY AREA: We conducted herpetofaunal surveys at ARNWR, which is located on the northeastern coast of NC (Fig. 2). **ARNWR covers 616 km² and occupies most of a peninsula (surrounded by brackish water to saltwater, connected to the mainland by a 5 x 13 km strip). ARNWR was established to conserve and protect pocosin wetland habitat and its associated wildlife species.** About 70% of ARNWR is a wetland in transition from partially ditched or drained areas with altered native vegetation to older forest swamps and pocosins. The remainder of the area is 20% natural wetlands and 10 % developed (Sharitz and Gibbons 1982).

Major habitat types on the refuge include second growth, pine-hardwood forest swamps (MFS, western side), pocosin wetlands (PW, eastern side), and to a lesser extent, lowland mixed pine and Atlantic white cedar [*Chamaecyparis thyoides* (L.)]. Swamp forests (MFS) are dominated by black gum [*Nyssa sylvatica* var. *biflora* (Walter) Sargent] and red maple (*Acer rubrum* L.) (Fig. 1 and 3). Planted loblolly (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm.) stands occupy higher drained areas. Pocosin (PW) vegetation is variously described as boggy shrublands or flatwoods usually dominated by broad-leaved evergreen shrubs (Fig. 1) or low trees (Sharitz and Gibbons 1982). Pocosins contain low nutrient, peaty soils that are poorly drained. The low elevation on the refuge, <1 to 5 m above sea level, allows saltwater invasion (flooded and killed areas), especially in areas peripheral to saltwater habitats and during storm surge events, which creates patchy habitats.

Most refuge roads (265 km) parallel canals (Fig 4.), which were created by road building and by draining of surrounding land for planned or former agricultural use (Braswell and Wiley 1982). **Although no major streams exist on the eastern side of the refuge, on the western side Milltail Creek (Fig. 3) flows west from the center of the refuge to Croatan Sound (Fig. 1).**

STOP!
Eastern Cottonmouth
on ARNWR road

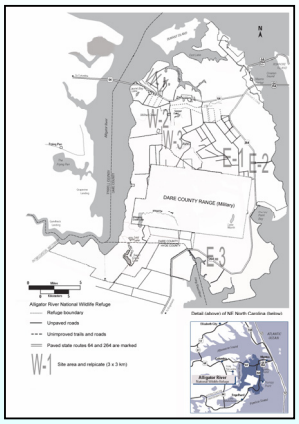

Fig. 2. Alligator River National Wildlife Refuge study areas, E-1 (PW,1st replicate) to W-3 (MFS, 3rd replicate).

Fig. 3. Milltail Creek, ARNWR.

Fig. 4. Drift fence, road, and canal.

METHODS:

- **We randomly established three 3 x 3 km sites in MFS and PW.** We selected large sites (900 ha) to prevent past land uses (e.g., 100-200+ ha clearcuts) from significantly affecting one site. We located one additional site (~1 x ~1 km) in the largest stand of Atlantic white cedar (AWC, Fig. 2).
- We sampled in September 2000 and more intensively from March to August 2001. **We used a variety of methods to collect and survey, including time- and distance-constrained visual encounter surveys along canals, time-constrained transects and quadrats, drift fences, nighttime frog call surveys, baited turtle traps, coverboards, and incidental encounters** (Campbell and Christman 1982, Dodd 2003, Vogt and Hine 1982, Heyer et al. 1994, Ryan et al. 2002).
- **We randomly located canal surveys monthly** from May to July in MFS and PW sites (3 x 6) and in the AWC site (n = 21 surveys). **While walking parallel along canals for 1.6 km, we visually surveyed for all reptiles and amphibians for 60 minutes** (Heyer et al. 1994).
- **We randomly located paired transects (parallel and 10 m apart) at 9-11 locations on each site from March to late June (n = 126 transects, including 6 in AWC).** Transects began 15 m from adjacent canals, perpendicular to the canals and roads, and proceeded away from the roads. **We searched transects an average of 9 min and 188 m** (distance calculated by Global Positioning System, GPS).
- **We randomly placed 3 drift fences in each site (n = 21, including 3 in AWC) along unpaved refuge roads (Fig. 4).** Roads were the only locations with consistently high elevations for drift fences and usually remained unflooded. We placed funnel traps in the middle of each fence beginning halfway through the trapping period.
- **We opened drift fences on a rotating schedule, with 3 MFS sites (and white cedar site) open for two days (total = 10 days) and the remaining 3 PW sites open for the next two consecutive days (total = 9 days) for a total of 19 days from April to July.**
- We placed turtle traps in canals near each drift fence and checked and rebaited them daily (sardines, chicken, and crabs) for three trap-nights during 8 June to 18 July 2005. Four coverboards (1.5 m²/board) were randomly placed (2 boards near 2 drift fence locations) in each PW and MFS site (n = 12) and at the AWC site (n = 2) in May and were checked once monthly thereafter for three months.

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METHODS (cont.):

- **We also recorded each reptile or amphibian incidentally encountered and its site (PW, MFS, or AWC with and GPS** (Fig 5).
- **ANALYSIS: We used species richness analysis developed by Nichols et al. (1998a, 1998b) and Hines et al. (1999), which accounts for differences in detection rates between PW and MFS areas, to estimate richness and compare community composition between the wetland pocosin (PW) and mixed forest swamp (MFS) sites of ARNWR. Program COMDYN4 (available at: www.mbr-pwrc.usgs.gov/software.html) was used to calculate these estimates.**
- **We made every effort to spend equal effort searching each area using the same techniques** (Nichols et al. 1998a, 1998b). We used all surveys combined (except incidental captures) within each site to calculate species presence or absence in the sites for use in COMDYN4. **Amphibian and reptilian species richness was analyzed separately with COMDYN4.**
- **We calculated species diversity using the Shannon-Wiener index, H', and evenness index, J',** which varies from 0 (completely uneven distribution of individuals by species) to 1 (all species have equal number of individuals) (Pielou 1966). J' equals H' divided by the maximum for H', given the number of species and individuals surveyed (Lloyd and Ghelardi 1964 in Krebs 1999). **PW and MFS areas were compared by combining all sampling methods except nighttime aural surveys (no individual count data) to produce a sample of species and individuals** collected with the same effort and methods. We tested differences between H' using Hutcheson's (1970) method.
- We used a community percentage similarity index (Renkonen 1938 in Krebs 1999, Whittaker 1975) to determine differences in PW and MFS herpetofaunal communities using the sample of species and individuals collected for diversity analysis. This simple index is one of the best quantitative similarity coefficients available (Wolda 1981).

Fig 5. Incidental capture, measurement, and release of kingsnake and mud turtle.

Fig. 6. Southeastern five-lined skink recorded on a transect survey.

RESULTS

- We found a total of 39 species present at 7 ARNWR sites, consisting of 28 reptiles and 11 amphibians. Incidental captures located 38 of 39 species that we observed elsewhere (Table 1).
- We found an additional 10 species on the refuge, but these were located by searching outside of our 7 sites in selected habitats (e.g., old dumps). Accordingly, we found a total of 49 species on ARNWR during 2000-2001. AWC habitat contained 12 species and 38 individuals, all similar to species found in MFS and PW sites.

Table 1. Number of amphibian and reptile species and relative abundance by survey method, ARNWR, NC, 2000-2001.

Survey Method	No. spp.	No. individ.	No. Amphib. spp	No. Reptile spp
Incidental capture	38	317	10	28
Canal transect	29	110	12	17
Drift fences	16	240	7	9
Transects and quad.	14	347	5	9
Nighttime aural	14	ND	14	0
Turtle traps	6	36	0	6
Coverboards	2	3	1	1

- **Using COMDYN4, we estimated 39 species in MFS and 32 species in PW sites (Table 2).** We found similar numbers of species in common for MFS and PW (Table 2). COMDYN's Model M_a from Nichols et al. (1998a) adequately fit ($P > 0.10$) all data for these estimates (Table 2).
- **We found no difference between species detectability probabilities between MFS and PW (Table 2 and 3). Therefore, we used actual numbers of species observed (more powerful) to calculate differences between PW and MFS areas (altLAMBDA in COMDYN4, Eq. 3 in Nichols et al. 1998a).**

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Table 2. Estimates of quantities for **herpetofaunal community parameters** of mixed forest swamp (MFS) and pocosin wetland (PW) sites, ARNWR, NC.

Quantity	Number sampled	Estimate	SE	95% CI
Species richness $N_{(pw)}$	28	32.4	3.6	28.0-41.3
Species richness $N_{(mfs)}$	33	39.2	4.0	33.0-47.8
Spp. present in MFS and PW	22	25.8	3.9	19.5-35.3
Spp. present in PW and MFS	22	24.0	3.5	18.0-31.7
Proportion of PW spp in MFS	-	0.92	0.10	0.67-1.00
Proportion of MFS spp in PW	-	0.73	0.11	0.56-1.00
Estimated ratio of sp richness est. as $N_{(mfs)}$ /$N_{(pw)}$	-	1.21	0.16	0.93-1.54
Estimated ratio of sp richness est. using actual spp sample	-	1.19	0.12	0.94-1.38
Spp not in PW, present in MFS	9	9.42	5.15	0.00-20.5
Est. spp detection prob. (PW)	1.0	0.86	0.09	0.68-1.00
Est. spp detection prob. (MFS)	1.0	0.84	0.09	0.69-1.00

- We found more reptile species (+31%) in MFS sites than in PW (Table 3 in bold).
- We estimated an identical number of amphibians species (17) in MFS and PW.
- Diversity (H') was higher ($P < 0.0001$) for PW (2.67) than for MFS (2.15) because of lower evenness (J') in the latter (0.62 vs. 0.80).
- Dominance of 3 *Rana* species caused low evenness, J', and lower diversity, H', in MFS (Fig. 7).
- Similarity between the communities was 56.6%; we estimated 22-24 species in common for each habitat (95% CI = 18 to 31 spp.).
- We verified 49 of the 52 herpetofaunal species on the refuge that were known to exist in the area.

Table 3. Estimates of quantities for **reptile community parameters** of mixed forest swamp (MFS) and pocosin wetland (PW) sites, ARNWR, NC.

Quantity	Number sampled	Estimate	SE	95% CI
Species richness $N_{(pw)}$	13	15.7	2.6	13.0-22.6
Species richness $N_{(mfs)}$	17	19.0	2.3	17.0-25.2
Spp. present in MFS and PW	9	12.2	2.7	7.3-17.2
Spp. present in PW and MFS	9	11.0	2.9	7.3-17.2
Proportion of PW spp in MFS	-	0.94	0.15	0.53-1.00
Proportion of MFS spp in PW	-	0.64	0.17	0.33-1.00
Estimated ratio of sp richness est. as $N_{(mfs)}$ /$N_{(pw)}$	-	1.21	0.21	0.82-1.66
Estimated ratio of sp richness est. using actual spp sample	-	**1.31**	**0.17**	**1.00-1.70**
Spp not in PW, present in MFS	8	4.3	3.6	0.00-13.09
Est. spp detection prob. (PW)	1.0	0.83	0.12	0.57-1.00
Est. spp detection prob. (MFS)	1.0	0.89	0.10	0.66-1.00

DISCUSSION AND MANAGEMENT IMPLICATIONS:

- The mainland adjacent to ARNWR contains 14 more species than the refuge, for a total 63 species in the region (28% more than at ARNWR, Braswell and Wiley 1982, Palmer and Braswell 1995). Of these additional species, 6 are amphibians and 8 are reptiles. Therefore, species richness on ARNWR could potentially increase, depending on management in the narrow land bridge to the south of the refuge.
- MFS and PW have 2 distinct herpetofaunal communities (56% similarity) and should be managed to maintain that difference and diversity.
- Dominance of *Rana* spp., found worldwide, may be caused by unnatural environments, disturbances (in past), or lack of salamander predators in the community. This dominance reduced diversity, H', in MFS sites.
- Managers should maintain herpetofaunal diversity in MFS and PW.
- COMDYN4 provides species detection probabilities and community parameters necessary for longterm monitoring at ARNWR and for upcoming restoration of water flow at the refuge.

Fig. 7. Large numbers of *Rana* spp. caused lower diversity (H').

Safe to go to next poster!
Eastern Kingsnake