SYNDROMIC SURVEILLANCE FOR WEST NILE VIRUS USING DATA OF RAPTORS IN REHABILITATION
Continuous collection and analysis of available data on animal health that precede the diagnosis to identify or predict possible disease outbreaks.
15 The Introduction and Emergence of Wildlife Diseases in North America

Robert G. McLean

Emerging infectious diseases in wildlife

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Infection and Disease in Reservoir and Spillover Hosts: Determinants of Pathogen Emergence

P. W. Daniels · K. Halpin · A. Hyatt · D. Middleton

SYNOPSIS

Wildlife, Exotic Pets, and Emerging Zoonoses

Bruno B. Chomel, Albino Belotto, and François-Xavier Meslin

Wildlife as Source of Zoonotic Infections

Hilde Kruau, Anne-Mette Kirkemo, and Kjell Handvold

Emerging Infectious Diseases • www.cdc.gov/ed • Vol. 10, No. 12, December 2004

The challenge of emerging and re-emerging infectious diseases

David M. Morens, Gregory K. Folkers, & Anthony S. Fauci
Nature 430, 242-249 (8 July 2004)
Critical points of using wildlife rehabilitation data for syndromic surveillance

- Lack of comprehensive, integrated database systems
- Limited infrastructure for wildlife rehabilitators
- Data quality-, integrity-, and timeline-related issues
- Specific surveillance goals and objectives
Minnesota - USA

Use of data gathered from The Raptor Center

~603 km X ~564 km
Retrospective data between Jan 1990 and Des 2014

TRC 2015 Clinic Patient Totals

In 2015, our clinic admitted 843 wild raptor patients. You can see the species census on our blog post.

Read more
AIMS

Assess the utility of the wildlife rehabilitation data to support early detection and monitoring of wildlife pathogen activity related to public, food animal, and environmental health.

WEST NILE as a PROOF OF CONCEPT:

Would the incursion of WNV in Minnesota result in aberrations in raptor rehabilitation data that would be detectable via syndromic surveillance?
West Nile

FAQs about West Nile Virus In Raptors

Q. Have there been any cases of West Nile virus in raptors?
A: Yes. West Nile virus had caused death in raptors in many parts of the United States, most since July 2002.

Q: Has the Raptor Center treated birds suffering from West Nile virus?
A: Yes. Between August and October 2002, the Raptor Center admitted 70 birds suspected of having the West Nile virus. About 60 of those died.

Q: What are the symptoms of West Nile virus in raptors?
A: There seem to be three phases, specifically --

**Phase 1:** Depression, anorexia, weight loss (in proportion to duration of anorexia), sleeping, pinching off blood feathers. Elevated white cell count.

**Phase 2:** In addition to the above, head tremors, green urates (indicating liver necrosis), mental dullness/central blindness and general lack of awareness of surroundings, ataxia (clumsiness), weakness in legs.

**Phase 3:** More severe tremors, seizures.
Microsoft Access
Relational Database
Data quality

Basic traits of the study population:

- spatiotemporal coverage
- avian group
- species
- age
- clinical signs
- state found
Total number of admissions from Minnesota

13696
FREQUENCY OF RAPTORS RECEIVED AT TRC BY MONTH

SEASONAL PATTERN AND INCREASING TRENDS

Jan 1990- Dec 2001
P5 - 11, Md - 32, P95 - 74

Jan 2002- Dec 2014
P5 - 16, Md - 42, P95 - 113

Admitted Raptors. Total: 13081
### FREQUENCY OF SPECIES (Period 1990 - 2014)

<table>
<thead>
<tr>
<th>Species</th>
<th>Nr of admissions</th>
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<tbody>
<tr>
<td>Turkey Vulture</td>
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<tr>
<td>Trumpeter Swan</td>
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<td>Swainson's Hawk</td>
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<td>Snowy Owl</td>
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<td>Short-Eared Owl</td>
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<td>Sharp-Shinned Hawk</td>
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<td>Screech-Owl (Eastern)</td>
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<td>Saw-Whet Owl (Northern)</td>
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<td>Rough-Legged Hawk</td>
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<td>Red-Tailed Hawk</td>
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<td>Red-Shouldered Hawk</td>
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<td>Prairie Falcon</td>
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<tr>
<td>Peregrine Falcon</td>
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<td>Other (or unknown)</td>
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<tr>
<td>Osprey</td>
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<td>Merlin</td>
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<td>Long-Eared Owl</td>
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<td>Kestrel (American)</td>
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<td>Hynd Falcon</td>
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<td>Hawk-Owl (Northern)</td>
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<td>Harris's Hawk</td>
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<td>Harrier (Northern)</td>
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<td>Harpy Eagle</td>
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<td>Gyrfalcon</td>
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<td>Great Horned Owl</td>
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<td>Great Gray Owl</td>
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<td>Goshawk (Northern)</td>
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<td>Golden Eagle</td>
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<td>Ferruginous Hawk</td>
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<td>Cooper's Hawk</td>
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<td>Common Barn-Owl</td>
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<td>Burrowing Owl</td>
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<tr>
<td>Broad-Winged Hawk</td>
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<td>Boreal Owl</td>
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<td>Barred Owl</td>
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<tr>
<td>Bald Eagle</td>
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</tbody>
</table>

28 Raptor species
CLINICAL SIGNS GROUPED BY ORGAN OR SYSTEM

- Assymetrical wing beats
- Injured but alert/feisty
- Unable to fly or stand
- Moderate weight loss (not emaciated)

* Affected organs

1. Other
2. Systemic
3. Integumentary
4. Musculoskeletal
5. Ear and Eyes
6. Nervous
7. No problems
8. Gastrointestinal
9. Respiratory
91. Renal

* assymetrical wing beats, injured but alert/feisty, unable to fly or stand, moderate weight loss (not emaciated)
FREQUENCY BY AVIAN GROUP AND AGE CATEGORY

Counts of admissions between July and October
CRITERIA

- Visual evidence of pattern change
- Significant changes before and after 2002
- WNV-like clinical signs
  \[\text{(Ellis et al., 2007; Wünschmann et al., 2005).}\]
- Corroboration with laboratorial diagnosis
EXPLORATION OF GROUPED TIME SERIES

TOTAL of RAPTORS ADMISSIONS

AVIAN GROUP

AGE

CLINICAL SIGNS

by SYSTEM / ORGAN
FREQUENCY OF GROUPS OF RAPTORS

Total: 5,279 39%
FREQUENCY OF CLINICAL SIGNS IN HAWKS ADMITTED BY MONTH

- **Hawk group with systemic signs** Total no.: 2611
  - Adult: P5 - 0 Md - 2 P95 - 5
  - Hatch year: P5 - 0 Md - 3 P95 - 11

- **Hawk group with nervous signs** Total no.: 657
  - Adult: P5 - 0 Md - 1 P95 - 4
  - Hatch year: P5 - 0 Md - 1 P95 - 5

- **Hawk group with integumentary signs** Total no.: 2343
  - Adult: P5 - 0 Md - 1 P95 - 4
  - Hatch year: P5 - 0 Md - 2 P95 - 9

- **Hawk group with gastrointestinal signs** Total no.: 356
  - Adult: P5 - 0 Md - 0 P95 - 1
  - Hatch year: P5 - 0 Md - 0 P95 - 2

- **Hawk group with ear and eye clinical signs** Total no.: 1192
  - Adult: P5 - 0 Md - 0 P95 - 3
  - Hatch year: P5 - 0 Md - 1 P95 - 5

- **Hawk group with respiratory signs** Total no.: 274
  - Adult: P5 - 0 Md - 0 P95 - 1
  - Hatch year: P5 - 0 Md - 0 P95 - 2
LABORATORIAL VALIDATION

Confirmed case of WNV case in raptor
Individual or pooled tissues (brain, heart, kidney)
positive to

✓ WNV RNA by PCR \(\text{(Lanciotti et al., 2000)}\)

or

✓ WNV Ag immunohistochemistry
\(\text{(Wüenschmann et al., 2014).}\)
WNV CASES CONFIRMED BY LAB. TESTS
(PERIOD 2007 - 2014)

333 raptors suspicious for WNV

162 (49%) WNV positive

110 (68%) hawks

88 (80%) hatch year birds
How to quantify the magnitude of this change?

INTERRUPTED TIME SERIES ANALYSES

Before WNV incursion

After WNV incursion

P5 - 1  Md - 7.5  P95 - 25

P5 - 3  Md - 13  P95 - 60
CRITERIA: Visual evidence + Significant changes before and after 2002 + WN-like clinical signs

Time unit: aggregated by month
Clustering: hawks with WNV-like clinical signs
Spatial unit: state
ANALYSIS OF INTERRUPTED TIME SERIES IN RAPTORS IDENTIFIED AS INDICATORS

\[ Y_t = [(\mu + \delta(t) + \alpha \cos(\omega t) + \beta \sin(\omega t) + \cdots + I_t \cdot t) +\]

\[ +[(\mu' + \delta'(t) + \alpha' \cos(\omega t) + \beta' \sin(\omega t) + \cdots)](1 - I_t \cdot t)] + \varepsilon_t \]

Linear trend  Cyclical components  Dummy variable  (before and after 2002)

\[ \varepsilon_t = \varphi_1 \varepsilon_{t-1} + \cdots + \varphi_p \varepsilon_{t-p} + \cdots + Z_t + \theta_1 Z_{t-1} + \cdots + \theta_q Z_{t-q}, \]

Error with ARMA model structure
FITTED INTERRUPTED TIME SERIES IN RAPTORS IDENTIFIED AS INDICATORS OF WEST NILE VIRUS

Follow up by mo.

- Observations: Total 4602
  - Fitted before Jan-2002: Total 1375
  - Fitted after Dec-2001: Total 3227

Jan 1990- Dec 2001
P5 - 1  Md - 8  P95 - 25

Jan 2002- Dec 2014
P5 - 3  Md - 13  P95 - 60
AFTER 2002 during months of summer the hawks admitted with WNV like clinical signs increased more than 3 times.
DISCUSSION
&
Some conclusions
Discussion and conclusions

Near real-time analysis of rehabilitation data within a syndromic surveillance framework

- potentially contribute to the detection of health anomalies and monitoring of animal health trends in wildlife populations.
Discussion and conclusions

• Raptors are placed at the top of the food chain and occupy broad areas, monitoring of raptor admissions may help to monitor the health status of other populations in the ecosystem.
Discussion and conclusions

Not only analyse **overall trends**, but also identify aberrations or trends when data is **subset by taxomony, age, and suites of clinical signs**.
Animals admitted into the rehabilitation centers may not be representative of the status of the wildlife population because animal collection is linked to the human activity ...
Discussion and conclusions

The lack of specificity of clinical signs.

- Assessment of underlying patterns
  - species,
  - age
  - clinical signs

- Laboratorial confirmation
.... more CONCLUSIONS

• Monitoring data from wildlife rehabilitation centers may help to target populations at high-risk and disease trends.

• Digital medical records with standardized data sets and terminology would help advance syndromic surveillance in wildlife.
Syndromic surveillance for West Nile virus using raptors in rehabilitation

Alba Ana1,2, M. Perez Andrés1, Ponder Julia1, Puig Pedro2, Wünschmann Arno1, Vander Waal Kimberly1, Alvarez Julio1 and Willette Michelle1

Abstract

Background: Wildlife rehabilitation centers routinely gather health-related data from diverse species. Their capability to signal the occurrence of emerging pathogens and improve traditional surveillance remains largely unexplored. This paper assessed the utility for syndromic surveillance of raptors admitted to The Raptor Center (TRC) to signal circulation of West Nile Virus (WNV) in Minnesota between 1990 and 2014. An exhaustive descriptive analysis using grouping time series structures and models of interrupted times series was conducted for indicator subsets.

Results: A total of 13,080 raptors were monitored. The most representative species were red-tailed hawks, great horned owls, Cooper’s hawks, American kestrels and bald eagles. Results indicated that temporal patterns of admissions at the TRC changed distinctively after the incursion of WNV in 2002. The frequency of hawks showing WNV-like signs increased almost 3 times during July and August, suggesting that monitoring of hawks admitted to TRC with WNV-like signs could serve as an indicator of WNV circulation. These findings were also supported by the results of laboratory diagnosis.

Conclusions: This study demonstrates that monitoring of data routinely collected by wildlife rehabilitation centers has the potential to signal the spread of pathogens that may affect wild, domestic animals and humans, thus supporting the early detection of disease incursions in a region and monitoring of disease trends. Ultimately, data collected in rehabilitation centers may provide insights to efficiently allocate financial and human resources on disease prevention and surveillance.

Keywords: Wildlife rehabilitation, Syndromic surveillance, Raptors, Big data, Time series, West Nile

Background

Wild animals play a key role in the transmission of many infectious diseases into humans by serving as reservoirs for important pathogens such as West Nile virus (WNV), avian influenza virus (AIV), and Lyme disease. Animal health surveillance may contribute to the early detection and prevention of disease outbreaks in human populations [1–3]. In addition to human health, the industries involved

Although there are systems in place for monitoring infectious diseases in humans and some domestic animals, as well as some programs for specific diseases in free-ranging wildlife, there is currently no comprehensive, integrated strategy for monitoring wildlife health issues in the United States [5]. Furthermore, although the need for such a monitoring system has been identified, challenges such as cost, time, case acquisition, and practicality of sampling...
### Table 1: Summary of the raptors received at The Raptor Center between 1990 and 2014 from Minnesota State

<table>
<thead>
<tr>
<th>Avian Group</th>
<th>Species</th>
<th>Nr and % admitted at The Raptor Center</th>
<th>Habitat</th>
<th>Food</th>
<th>Migration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawks</td>
<td>Red-Tailed Hawk <em>Buteo jamaicensis</em></td>
<td>2360</td>
<td>13.5%</td>
<td>RIME, FO, PA, RO, UR, SM, BIRE, FL, IN, CA</td>
<td>PM, NM</td>
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<tr>
<td></td>
<td>Cooper's Hawk <em>Accipiter cooperi</em></td>
<td>1538</td>
<td>11.3%</td>
<td>FO, WB, PA, BLS, RE, AM</td>
<td>M, PM</td>
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<tr>
<td></td>
<td>Broad-Winged Hawk <em>Buteo platypterus</em></td>
<td>618</td>
<td>4.7%</td>
<td>FO, WB, PA, BL, IN, RE, AM, SM</td>
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<td></td>
<td>Sharp-Shinned Hawk <em>Accipiter striatus</em></td>
<td>380</td>
<td>2.9%</td>
<td>WB, FO, PA, BLS, RE, AM</td>
<td>M, PM</td>
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<tr>
<td></td>
<td>Red-Shouldered Hawk <em>Buteo lineatus</em></td>
<td>145</td>
<td>1.1%</td>
<td>W, B, FO, PA, RO, IN, BIRE, AM</td>
<td>M, PM</td>
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<tr>
<td></td>
<td>Rough-Legged Hawk <em>Buteo lagopus</em></td>
<td>123</td>
<td>0.9%</td>
<td>OF, FL, PA</td>
<td>SM, M</td>
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<td>Goshawk (Northern) <em>Accipiter gentilis</em></td>
<td>95</td>
<td>0.7%</td>
<td>OF, WB, PA, SM, B1</td>
<td>NM</td>
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<td>Swainson's Hawk <em>Buteo swainsoni</em></td>
<td>18</td>
<td>0.1%</td>
<td>OF, FL, ERO, SM, IN, RE, BI</td>
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<td></td>
<td>Ferruginous Hawk <em>Buteo regalis</em></td>
<td>3</td>
<td>0.0%</td>
<td>OF, FL</td>
<td>SM, IN, RE, BI</td>
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<tr>
<td>Owls</td>
<td>Great Horned Owl <em>Bubo virginianus</em></td>
<td>2148</td>
<td>16.4%</td>
<td>FO, WB, B, SM, IN, BI</td>
<td>NM</td>
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<td>Barred Owl <em>Bubo varius</em></td>
<td>797</td>
<td>6.1%</td>
<td>FO, WB, PA, SI, SM, FL, RE, AM</td>
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<td>Saw-Whet Owl (Northern) <em>Aegolius acadicus</em></td>
<td>372</td>
<td>2.8%</td>
<td>FO, WB, RO, SM, BIRE</td>
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<td>Screech-Owl (Eastern) <em>Megascops asio</em></td>
<td>368</td>
<td>2.8%</td>
<td>FO, WB, PA, IN, SM, BIRE</td>
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<td>Great Gray Owl <em>Strix nebulosa</em></td>
<td>197</td>
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<td>Long-Eared Owl <em>Asio otus</em></td>
<td>136</td>
<td>1.0%</td>
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<td>B1, NM, IR</td>
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<td></td>
<td>Snowy Owl <em>Asio flammeus</em></td>
<td>111</td>
<td>0.8%</td>
<td>BOME, FO, FL, LA, TU, IN, SM, BIRE</td>
<td>M</td>
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<td>Short-Eared Owl <em>Asio flammeus</em></td>
<td>92</td>
<td>0.7%</td>
<td>FL, EM, ME, OP</td>
<td>SM, B1</td>
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<td></td>
<td>Boreal Owl <em>Surnia ulula</em></td>
<td>8</td>
<td>0.1%</td>
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<td>NM, IR</td>
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<tr>
<td>Hawks-Owl (Northern)</td>
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<tr>
<td>Falcons</td>
<td>Kestrel (American) <em>Falco sparverius</em></td>
<td>1347</td>
<td>10.3%</td>
<td>FO, WB, CL, FP, PA, RO, UR, IN, SM, BIRE</td>
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<td></td>
<td>Peregrine Falcon <em>Falco peregrinus</em></td>
<td>300</td>
<td>2.3%</td>
<td>RI, LA, FO, CL, RO, UR</td>
<td>BI, M</td>
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<td>Merlin <em>Falco columbarius</em></td>
<td>244</td>
<td>1.9%</td>
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<td>Prairie Falcon <em>Falco mexicanus</em></td>
<td>6</td>
<td>0.0%</td>
<td>OF, FL, ERO, PA, RO, CL, SM, IN, RE, BI</td>
<td>M, NM, IR</td>
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<tr>
<td>Eagles</td>
<td>Bald Eagle <em>Haliaeetus leucocephalus</em></td>
<td>1193</td>
<td>9.1%</td>
<td>LA, RI, B, FI, CA, BI</td>
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<td>Golden Eagle <em>Aquila chrysaetos</em></td>
<td>15</td>
<td>0.1%</td>
<td>MO, CL, VA, SM, BIRE, IN, CA</td>
<td>M, PM</td>
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<td>Others</td>
<td>Osprey <em>Pandion haliaetus</em></td>
<td>225</td>
<td>1.7%</td>
<td>LA, RI, FL, RE, AM, BI</td>
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<td>Turkey Vulture</td>
<td>132</td>
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<td>OF, FL, RI, RO, CA</td>
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<td>Harrier (Northern) <em>Circus cyaneus</em></td>
<td>68</td>
<td>0.5%</td>
<td>FI, MA, WE, ME, PA, SM, IN, RE, BI</td>
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**CODES:**

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<tr>
<td>Migration</td>
<td>M: complete migratory</td>
<td>NM: non-migratory</td>
<td>PM: partial migratory</td>
<td>IR: irruptive</td>
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Human cases and admissions of raptor sentinels for WNV

p-value = 0.009976**
Kendall tau  0.55
ADMISSIONS OF GREAT HORNED OWL DIFFERENTIATED BY CLINICAL SIGNS

- Unespecific
- Systemic
- Integumentary
- Musculoskeletal
- Ear and eye clinical signs
- Neurological
- No signs
- Gastrointestinal
- Respiratory
- Renal
Signes cliniques systémiques  
Total : 2611

Signes cliniques tégumentaires  
Total : 2343

Signes cliniques auriculaires et oculaires  
Total : 1182

Signes cliniques nerveux  
Total : 657

Signes cliniques gastro-intestinaux  
Total : 356

Signes cliniques respiratoires  
Total : 274