A LANDSCAPE APPROACH TO RESERVING FARM PONDS INTO WINTERING BIRD REFUGES IN TAOYUAN, TAIWAN

By
Dr. FANG, WEI-TA
Asian Flyway Migration Routes

US Central Flyway Migration Routes

Break News form [Houston Chronicle] Nov 26, 2004

USA: $32 billion/year for birding;
46 million people belonging birders

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<th>Houston-Galveston</th>
<th>Taoyuan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Size</td>
<td>696,000km² (919.42)</td>
<td>36,000km² (47.5)</td>
<td>2,100km² (2.77)</td>
<td>757km² (1)</td>
</tr>
<tr>
<td>Human Population</td>
<td>22.1m</td>
<td>22.7m</td>
<td>2.0m</td>
<td>1.8m</td>
</tr>
<tr>
<td>Bird Species</td>
<td>606</td>
<td>476</td>
<td>320</td>
<td>94</td>
</tr>
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</table>

Opportunities and Challenges

- Good news: By the species numbers and specific location, Taiwan waters a midway stopover for wintering birds;
- Bad news:
  - No official census to emphasize economic clouts of birding and/or avi-tourism in Taiwan.
  - Happy birding is belonging to few birders as well as none bird refuge was formed on the Taoyuan Tableland, Taiwan.
  - Birds are more difficult to find stopovers and/or refuges than ever because of pond loss due to urbanization on the Tableland.
Opportunities and Challenges

- Good News: One fifth of all bird species find home on farm ponds in Taoyuan, Taiwan.
- Bad News:
  - The area of farm ponds accounted for 11.8% (8,900 ha) by area of the Taoyuan Tableland (1870s); by 2002 the area of farm ponds only accounted for 3.8% of the land area (2,898 ha).
  - If a pond area of 1 ha can support 7 birds, the ones of pond loss that comprised the habitat should be estimated to support 42,000 individuals.
Flow Chart of Methods (I)

Data Survey
- Avian Data
  - Linear/Non-linear Models
  - Criteria Selection for Target Guild
  - ANN Simulation for Target Guild’ Diversity
- Pondscape
- Land-use
  - Logistic Regression
  - Logistic Simulation from Pond-loss Likelihood
- GIS Mapping
  - Gradients for Development Intensities
  - Priorities for Wintering Bird Refuges
Before Urbanized
The trends of progressive constructed areas in 1904
Before Urbanized-cont’d
The trends of progressive constructed areas in 1926
Urbanization

The trends of progressive constructed areas in 1960

[Map of urbanization trends in 1960]
Before Irrigation, Ponds in 1904
Before Irrigation, Ponds in 1926
After Irrigation, Ponds in 1960
After Irrigation and Consolidation, Ponds in 1999
Before 1960s
(Pond Loss 1926 ~ 1960)
After 1960s

Pond Loss 1960 ~ 1999

CKS International airport

New town project
Farm Ponds, Taoyuan, Taiwan (1926~1999)

- 56% of the pond area loss (1926~1999)
- 66% of the pond number loss (1926~1999)
- 1926~1960 Smaller ponds underwent changes due to urban and transportation development.
- 1960~1999 Smaller ponds underwent changes due to urban, transportation, and farmland consolidation (exception: larger ponds underwent changes due to airport and new town construction).
Hypothesis I

Smaller size underwent loss easily.

- Pond size and pond perimeter determine which ponds remain and which disappear.
  Pond size, the extent of water regimes, mudflats, and windbreaks, and shape determine the species richness, individuals, and diversity of wintering birds within ponds.

- Alternative hypothesis: Pond size and pond perimeter do not determine which ponds remain and which disappear.
  Alternative hypothesis: Pond size and shape do not determine the species richness, individuals, and diversity of wintering birds within ponds.
1926~1960 model: the larger the pond size, the less the likelihood of pond loss; the longer the perimeter of a pond, the less likelihood of pond loss.

Logit \( Y \) = 1.90 -3.02PS + 0.01TE

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Regression coefficient (( \beta ))</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond Size (PS)</td>
<td>-0.74</td>
<td>0.37**</td>
</tr>
<tr>
<td>LPI</td>
<td>-49.05</td>
<td>0.37**</td>
</tr>
<tr>
<td>MPS</td>
<td>-0.74</td>
<td>0.37**</td>
</tr>
<tr>
<td>MPFD</td>
<td>80.20</td>
<td>0.40**</td>
</tr>
<tr>
<td>MSI</td>
<td>-0.06</td>
<td>0</td>
</tr>
<tr>
<td>ED</td>
<td>0.03</td>
<td>0.50**</td>
</tr>
<tr>
<td>Pond Perimeter (TE)</td>
<td>0</td>
<td>0.26**</td>
</tr>
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</table>

0: pond losses by 1960, \( n = 1878 \);
1: ponds remaining in 1960, \( n = 2643 \), \( p \) value = **(0.005)
Farm Ponds, Taoyuan, Taiwan (1926~1960)

- $P_i = \text{Likelihood loss rate of a single pond} = \exp (1.90 -3.02PS + 0.01TE)/[1+\exp (1.90 -3.02PS + 0.01TE)]$

(model $N = 4521$, $R^2 = 0.47$, d.f. = 3). Plots met the expectations for the 1926~1960 model: the smaller the pond size, the greater the likelihood of pond loss ($R^2_{PS} = 0.37$, $\alpha = 0.005$, $\beta = 0.003$, power = 0.997); the shorter the perimeter of a pond, the greater the likelihood for pond loss ($R^2_{TE} = 0.26$, $\alpha = 0.005$, $\beta = 0.003$, power = 0.997).
# Logistic Simulation from Pond-loss Likelihood

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<tr>
<th>Land-use Intensities</th>
<th>Pond-loss Likelihood ($p$)</th>
<th>$PS$ (in ha)</th>
<th>$TE_{km}$ (in km)</th>
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<tr>
<td>Extremely Conservative</td>
<td>0.05</td>
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<td>0.7080</td>
<td>0</td>
</tr>
<tr>
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<td>0.2666</td>
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Flow Chart of Methods (II)

Data Survey
- Avian Data
  - Linear/Non-linear Models
  - Criteria Selection for Target Guild
  - ANN Simulation for Target Guild' Diversity
- Pondscape
- Land-use
  - Logistic Regression
  - Logistic Simulation from Pond-loss Likelihood

GIS Mapping
- Gradients for Development Intensities
- Priorities for Wintering Bird Refuges
Research Questions

How to preserve wintering bird refuges?

- How to find wintering bird refuges on the Taoyuan Tableland?
- How to survey hotspots for refuges?
- How to extrapolate hotspots for refuges?
- How to overlay potential bird refuges (i.e., high bird diversity) against likelihood loss rate of a single pond?
**Species-area Relationship**


- $S = cA^z$; where $S$ is species richness, $z$ is the slope, $A$ is the area, and $c$ is a constant.

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RANGELEAND ECOLOGY & MANAGEMENT
Species-area relationship is not governed by \( S = cA^z \), but may be driven by a log-log plot (Durreett and Levin 1996).

Species differ from one another in their responses to area (Hubbell 2001).

Species-habitat relationship: Habitat heterogeneity increases with an increase in area (Traut and Hosteler 2004).
Hypothesis II

Large/regular ponds attract more birds.

Pond size and pond perimeter determine which ponds remain and which disappear.

- Pond size, the extent of water regimes, mudflats, and windbreaks, and shape determine the species richness, individuals, and diversity of wintering birds within ponds.

Alternative hypothesis: Pond size and pond perimeter do not determine which ponds remain and which disappear.

- Alternative hypothesis: Pond size and shape do not determine the species richness, individuals, and diversity of wintering birds within ponds.
Methods

- Site Selected: 45 ponds, Taoyuan Tableland.
- Pond Sampled: More than 2 km from major urbanized corridors, far from natural forest areas in eastern regions.
- Pondscape Digitized: ponds, farmlands, roads, river, areas with structures.
Digitized Process

within a radius (564.19m) of 100 ha from the pond’s geometric center
**Normalized Process**

- **Mean Pond Fractal Dimension**
- MPFD = $2\ln TE / \ln PS$,  
  $TE = \text{pond perimeter}$,  $PS = \text{pond size}$  
- MPFD $\approx 1$, shape as circle or square
- MPFD $\approx 2$, shape with highly convoluted perimeter
Survey Results

- Bird and Pond Survey: Intensive 4-months around 45 ponds simultaneously.
- 94 species, 15,053 individuals counted on four occasions between November 2003 to February 2004.

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<tr>
<th>Dates</th>
<th>No. of species</th>
<th>No. of individuals</th>
</tr>
</thead>
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<tr>
<td>Nov 2003</td>
<td>60</td>
<td>3,721</td>
</tr>
<tr>
<td>Dec 2003</td>
<td>67</td>
<td>4,272</td>
</tr>
<tr>
<td>Jan 2004</td>
<td>62</td>
<td>3,900</td>
</tr>
<tr>
<td>Feb 2004</td>
<td>59</td>
<td>3,160</td>
</tr>
<tr>
<td>Total counts</td>
<td></td>
<td>15,053</td>
</tr>
</tbody>
</table>
Calculated Results

- Variation in spatial diversity (Shannon-Wiener index, $H'$) of wintering birds.

- $H' = - \sum Pi \log_2 Pi$

  $(Pi: \text{percentage of the } i \text{ species})$

Cluster analysis by Ward’s method (error of the sum of squares)

Overall birds (94)

Shorebirds (14)

Waterfowl (9)

Waterside birds (22)

Land birds (49)

Air feeders (10)

Grassland birds (6)

Scrubland bird (13)

Woodland bird (20)

pond core  mudflat  wet grass  scrub  wood

Water table
Correlation Analysis (waterside birds)

Linear regression

1. Waterside bird species richness had a negative correlation ($r = -0.48$) with the ratio of areas with permanent structures within a radius of 100 ha from the pond’s geometric center.

2. Waterside bird species richness had a positive correlation ($r = 0.40$) with the ratio of farmland areas within a radius of 100 ha from the pond’s geometric center.

3. Waterside bird individuals vs. pond size, $PS$, $r = 0.41$

4. Waterside bird species richness vs. pond shape, $MPFD$, $r = -0.32$
Model Finding

**Linear regression**

- Inappropriate land use of urban development in the surrounding farm-pond areas might pose a threat to the waterside bird group.
- Waterside bird groups were more sensitive to human disturbances, reserve isolation, and fragmentation than other guilds.
- The cumulative effects on pond area and shape were those that resulted from the interaction of anthropogenic influences, and they were statistically significant for the waterside group.
Linear regression

- Waterside bird diversity: lower and moderate relationships with PS, MPFD, %FARM, and %BUILD from the simple linear regression model ($r<0.28$).
Model Critique

**Linear regression**

- Low correlation coefficient \( (r) \) reflect low percentages of explained parameter;
- Not fit non-linear relationship; and
- Not fit interactions among parameters.
- No more information provided.
Nonlinear Modeling: Artificial Neural Network

- A simplified model of biological neural architecture
  - Multiple hypotheses need to pursued in parallel;
  - Enormous amounts of data need to be proceeded; and
  - The best current systems are far inferior to human performance.
Nonlinear Modeling:
Error Back-propagation
Artificial Neural Network

(training sets 35, validated sets 10, extrapolated sets 10)

\[ \phi(v) = \frac{1}{1 + \exp(-cv)} \]

\[ \sum \phi(v) \]

Programming by MATLAB 6.1
Nonlinear Modeling

Error Back-propagation (True $H'$ vs. ANN’s Predicted $H'$)

Hidden layers for 4 neurons
Training sets $r = 0.725537$
Validated sets $r = 0.722752$

Hidden layers for 2 neurons
Training sets $r = 0.686382$, validated sets $r = 0.702283$

Hidden layers for 8 neurons
Training sets $r = 0.735429$, validated sets $r = 0.651866$

Underfitting Training
Overfitting Training
Nonlinear Modeling: Finding

Modeling Significances (The test of mean error between true $H'$ and predicted $H'$)
(Neurons = 4, testing at a $\pm 10\%$ range, and see its performance)

(e.g., 1-PS, 1-MPFD, 1-%FARM, 1-%BUILD) → 1-PS, +1.1-MPFD, 1-%FARM, 1-%BUILD)

- Training sets ($r = 0.725537$, $n = 35$) and validated sets ($r = 0.722752$, $n = 10$) were able to meet the underlying rules embedded for real values in the true $H'$.

- MPFD (range = [1, 2]) has a strongly negative relationship with waterside bird diversity. With very simple perimeters such as circles or squares, then waterside bird diversity increases; and approaches 2 for shapes with highly convoluted, then waterside bird diversity declines.
Nonlinear Modeling: Finding

Modeling Significances (factor elimination)
(Neurons = 4, testing while factor-withdrawal in various scenarios, and see its performance)

(e.g., PS, MPFD, %FARM, %BUILD→ PS, %FARM, %BUILD)

4 parameters

- MPFD (↓), %FARM(↑), PS(↑), %BUILD(↓) are the major factors to increase and/or decrease waterside bird diversity ($H'$), respectively (see arrow’s direction).
- Extrapolation to predict the value of $H'$. 
Conclusion

- Ponds with larger size and longer perimeter are less likely to disappear.
- Smaller and more curvilinear ponds tend to have more drastic rate of loss.
- The result of ANN with four neurons shows a good-fit prediction against pond shape, neighboring farmlands, size, and neighboring developed constructed areas.
Flow Chart of Methods (III)

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    - Gradients for Development Intensities
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## Gradients for Development Intensities

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3.2. Determination of performance index
The preliminary evaluation whose large portion is based on the heuristic knowledge should be guided in a prudent way. The published provisions and handbooks give us valuable procedure and guidelines for the evaluation of individual performance index. After interpretation of available data and analysis the resulting performance indices are listed and reviewed for evaluation. However, deficiency and seriousness caused from multi-criteria cannot be easily assessed by listing the performance indices in descending order as recommended by NEHRP handbook [5]. To overcome this problem the following considerations are made in the seismic evaluation of this study:
1. Each performance index is expressed in terms of a normalized value for each performance criteria. Demand/capacity ratio and degree of irregularity are calculated first and then normalized.
2. Category weighting factors and subcategory weighting factors are used to reflect relative importance among the performance criteria defined at the same level. This is to

\[
\begin{align*}
\text{Likelihood Loss Rate (}\rho) & \quad 0.75 \\
\text{PS (in ha)} & \quad 0.5 \\
\text{IE (in km)} & \quad 1.5
\end{align*}
\]
Before Simulation-Land development intensities for 25% of Pond loss

Potential prioritized refuges
Designed for waterside birds

PS > 0.9962 ha, TE> 0.9971 km, bird loss no. >5,000
Before Simulation-Land development intensities for 50% of Pond loss

Potential prioritized refuges
Designed for waterside birds

PS > 0.6310 ha, TE > 0.7080 km, bird loss no. > 10,000
Before Simulation-Land development intensities for 75% of Pond loss

Potential prioritized refuges
Designed for waterside birds

PS > 0.2666 ha, TE> 0.3701 km, bird loss no. > 15,000
ANN Simulation-Land development intensities for 25% of Pond loss

Potential prioritized refuges
Designed for waterside birds

PS > 0.9962 ha, TE> 0.9971 km , bird loss no. >5,000
ANN Simulation-Land development intensities for 50% of Pond loss

Potential prioritized refuges
Designed for waterside birds

PS > 0.6310 ha, TE> 0.7080 km , bird loss no. >10,000
ANN Simulation-Land development intensities for 75% of Pond loss

Potential prioritized refuges Designed for waterside birds

PS > 0.2666 ha, TE> 0.3701 km , bird loss no. >15,000
ANN Simulation - Land development intensities for 75% of Pond loss

Potential prioritized refuges
Designed for waterside birds

PS > 0.2666 ha, TE > 0.3701 km, bird loss no. > 15,000
Welcome Home