WATERBIRD AND RAPTOR USE OF THE ARCATA MARSH AND WILDLIFE SANCTUARY, HUMBOLDT COUNTY, CALIFORNIA, 1984-1986

by

J. Mark Higley

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WATERBIRD AND RAPTOR USE OF THE ARCATA MARSH AND WILDLIFE SANCTUARY, HUMBOLDT COUNTY, CALIFORNIA, 1984-1986

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Approved by the Master's Thesis Committee

Stanley W. Harris, Chairman 10 Dec 1989

David W. Kitchen 12/11/89

Robert Gearhart 12/11/89

Director, Natural Resources Graduate Program

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Natural Resources Graduate Program Number

Approved by the Dean of Graduate Studies

Robert Willis 14/13/89
ABSTRACT

Waterbird use and aquatic vegetation structure of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California was studied from 9 May 1984 to 21 August 1986. Diurnal waterbird use of each marsh unit was determined by direct counts of all birds on each unit. An average of 2.4 surveys was conducted at high and also at low tide each week. Percent cover of the marsh units was determined by preparing cover maps from low altitude aerial photographs and standing crop biomass was calculated by harvesting samples from random plots.

In Gearheart Marsh the coverage of common cattail (Typha latifolia) nearly doubled between April 1985 and September 1987 while marsh pennywort (Hydrocotyle ranunculoides) nearly tripled. In September 1985 sago pondweed (Potamogeton pectinatus) covered 77.2 percent of Gearheart Marsh. The peak sago pondweed standing crop present in Gearheart Marsh was measured in June 1985 (187.94 grams per square meter ± 113.08 g) and in June 1986 (132.77 grams per square meter ± 88.73 g). Sago pondweed was not present in Hauser Marsh in 1985 because the unit was dry during the growing season but in September 1986, there were 93.03 (± 47.66) grams per square meter.

One hundred and seventy four species of birds were observed at the Marsh Project during this study. Of these, 98 species were observed on the water areas and are treated in this report. The total waterbird use-days in 1984-85 was 1,434,633 and 1,429,873 in 1985-86. Shorebirds represented 87.9 percent of all bird use-days and waterfowl, coots and rails accounted for 8.8 percent. Peak waterbird use occurred during winter, early and late spring in both years with 63.1 and 61.0 percent of the annual total bird use-days represented in those three seasons in 1984-85 and 1985-86 respectively. The lowest waterbird use occurred in summer with 0.48 and 0.42 percent of the total annual bird use-days in 1984-85 and 1985-86 respectively. Most waterbird
species using the Marsh Project either had no significant difference in use rates between tide levels or were found in significantly greater numbers at high tide (p<0.05).

Klopp Lake had the highest percent of the total bird use-days per five hectares in both years because of large and small shorebird use. Gearheart Marsh was second and Hauser Marsh was third in percent of total bird use-days per five hectares in both years because of puddle ducks, coots and diving ducks in Gearheart and coots and small shorebirds in Hauser Marsh.

Four bird groups were found in significantly different (p<0.05) numbers between years on a marsh-wide basis. The fish-eating diver group occurred in significantly lower numbers in 1985-86 compared to 1984-85 mostly because of reduced numbers of double-crested cormorants and "other" fish-eating divers in Klopp Lake. Puddle ducks doubled in numbers on a marsh-wide basis because of a 72 percent increase in Gearheart Marsh principally by green-winged teal (Anas crecca) and mallards (A. platyrhynchos). Large shorebirds significantly decreased (p<0.05) between 1984-85 and 1985-86 mostly because of a reduction of marbled godwits (Limosa fedoa) and willets (Catoptrophorus semipalmatus) in Klopp Lake. Gulls and terns significantly decreased (p<0.05) marsh wide between 1984-85 and 1985-86, mainly because of a reduction of more than 50 percent in gull and tern use-days at Klopp Lake.
ACKNOWLEDGMENTS

In eighth grade I decided that I wanted to pursue a master's degree in wildlife management. I had met several wildlife biologist and their jobs looked fascinating to me. They all recommended graduate school as the best way to break into the crowded field, so I set this goal. By the time I finished my undergraduate degree, I was still set on a master's degree, but for a different reason. I felt there was a lot more to learn!

I feel that the experiences and education that I've obtained will help me in every interest I chose to pursue. I've learned how to "learn" and for that I am forever indebted to Humboldt State University and all of the fine professors that I've encountered. Special thanks in that regard to Dr. Stan Harris, Dr. Terry Roelofs, Dr. George Allen and Dr. Robert Gearheart.

I can't thank Dr. Stan Harris, my major professor, enough for his incredible editorial skills, patience, subtle encouragement and most of all friendship. Special thanks to Dr. David Kitchen for agreeing to review this thesis in place of the late Dr. James Koplin. His editorial comments were enlightening. Dr. Robert Gearheart provided answers to many wastewater related questions I had, shared many stimulating ideas and always had an encouraging word for me, thank you!

I am grateful to the City of Arcata for allowing me the permits to conduct my research and for having such an innovative solution to their wastewater treatment needs and making the Marsh Project a reality. Special thanks to David Hull for his assistance with so many marsh project questions. Len, at Capital Business Machines, computer assistance was invaluable.

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>x</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>STUDY AREA</td>
<td>5</td>
</tr>
<tr>
<td>Uplands</td>
<td>5</td>
</tr>
<tr>
<td>Allen Marsh</td>
<td>5</td>
</tr>
<tr>
<td>Gearheart Marsh</td>
<td>9</td>
</tr>
<tr>
<td>Hauser Marsh</td>
<td>9</td>
</tr>
<tr>
<td>Klopp Lake</td>
<td>10</td>
</tr>
<tr>
<td>METHODS</td>
<td>12</td>
</tr>
<tr>
<td>Vegetation</td>
<td>12</td>
</tr>
<tr>
<td>Bird Use</td>
<td>13</td>
</tr>
<tr>
<td>Survey Technique</td>
<td>13</td>
</tr>
<tr>
<td>Seasonal Use</td>
<td>14</td>
</tr>
<tr>
<td>RESULTS</td>
<td>16</td>
</tr>
<tr>
<td>Vegetation</td>
<td>16</td>
</tr>
<tr>
<td>Waterbird Use</td>
<td>23</td>
</tr>
<tr>
<td>Effects of Tide Level</td>
<td>23</td>
</tr>
<tr>
<td>Seasonal Use</td>
<td>47</td>
</tr>
<tr>
<td>Waterbird Use Among Marsh Units and Between Years</td>
<td>68</td>
</tr>
</tbody>
</table>

vii
TABLE OF CONTENTS (continued)

DISCUSSION ......................................................................................................................... 88

Vegetation Growth Patterns ................................................................................................. 88
Sago Pondweed .................................................................................................................... 89

Avian Use .............................................................................................................................. 92
Waterbird Use at High and Low Tides .................................................................................. 94
Seasonal Use ........................................................................................................................... 94
Fish-Eating Divers ............................................................................................................... 95
Heron and Egrets ................................................................................................................ 96
Puddle Ducks ........................................................................................................................ 97
Diving Ducks ........................................................................................................................ 98
Coots and Rails ..................................................................................................................... 99
Large Shorebirds ................................................................................................................ 99
Small Shorebirds ............................................................................................................... 101
Gulls and Terns .................................................................................................................. 102
Raptors ............................................................................................................................... 103

Bird Use Among Marsh Units and Between Years ............................................................ 104
Management Implications .................................................................................................. 107

LITERATURE CITED ............................................................................................................. 112

APPENDIX

A. Seasonal Status of Water Birds and Raptors Recorded During 320 High Tide Surveys at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 ......................................................... 118
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Percent Cover of the Dominant Plant Species at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California Calculated from Aerial Photographs 1985 - 1987</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1984 and 9 May 1985 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses)</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses)</td>
<td>33</td>
</tr>
<tr>
<td>4</td>
<td>Frequent Species Bird Use-Days per Season and Percent of Yearly Total Bird Use-Days, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986</td>
<td>52</td>
</tr>
<tr>
<td>5</td>
<td>Annual Bird Use-Days per Five Hectares Within Each Marsh Unit at the Arcata Marsh And Wildlife Sanctuary, Humboldt County, California, 1984-85 and 1985-86</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>Comparison of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California With Three North Coast Wetland Areas, Noted For Waterbird Use</td>
<td>93</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Location of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Location of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>The Original 37.8 Hectares of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, With the Original Water Sources and Flow Patterns and the Approximate Location of the Bird Survey Points and Area Surveyed</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>The Water Flow Patterns and Potential Water Sources of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 1989-1990</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>Vegetation Cover of Gearheart Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>Vegetation Cover of Hauser Marsh in September 1987 of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California</td>
<td>19</td>
</tr>
<tr>
<td>7</td>
<td>Vegetation Cover of Allen Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California</td>
<td>20</td>
</tr>
<tr>
<td>8</td>
<td>Mean, Dry Weight, Standing Crop Biomass of Sago Pondweed For Gearheart Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California 1985</td>
<td>21</td>
</tr>
<tr>
<td>9</td>
<td>Mean, Dry Weight, Standing Crop Biomass of Sago Pondweed For Gearheart Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California 1986</td>
<td>22</td>
</tr>
<tr>
<td>10</td>
<td>Approximate Water Level Deviations from the Operating Level, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California</td>
<td>24</td>
</tr>
<tr>
<td>11</td>
<td>Mean Number of Fish Eating Divers per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>42</td>
</tr>
<tr>
<td>12</td>
<td>Mean Number of Herons and Egrets per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>43</td>
</tr>
<tr>
<td>13</td>
<td>Mean Number of Puddle Ducks per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>44</td>
</tr>
<tr>
<td>14</td>
<td>Mean Number of Diving Ducks per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>45</td>
</tr>
<tr>
<td>15</td>
<td>Mean Number of Coots and Rails per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>46</td>
</tr>
<tr>
<td>16</td>
<td>Mean Number of Large Shorebirds per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>48</td>
</tr>
<tr>
<td>17</td>
<td>Mean Number of Small Shorebirds per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>49</td>
</tr>
<tr>
<td>18</td>
<td>Mean Number of Gulls and Terns per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>50</td>
</tr>
<tr>
<td>19</td>
<td>Mean Number of Raptors per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys)</td>
<td>51</td>
</tr>
<tr>
<td>20</td>
<td>Bird Use-Days at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, by Bird Group, 9 May 1984 - 21 August 1986</td>
<td>56</td>
</tr>
<tr>
<td>21</td>
<td>Mean Number of Frequent Species of Fish Eating Divers per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>58</td>
</tr>
<tr>
<td>22</td>
<td>Mean Number of Frequent Species of Herons and Egrets per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>59</td>
</tr>
<tr>
<td>23</td>
<td>Mean Number of Frequent Species of Puddle Ducks per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>60</td>
</tr>
<tr>
<td>24</td>
<td>Mean Number of Frequent Species of Diving Ducks per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>61</td>
</tr>
<tr>
<td>25</td>
<td>Mean Number of Frequent Species of Coots and Rails per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>63</td>
</tr>
<tr>
<td>26</td>
<td>Mean Number of Frequent Species of Large Shorebirds per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>64</td>
</tr>
<tr>
<td>27</td>
<td>Mean Number of Frequent Species of Small Shorebirds per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>65</td>
</tr>
<tr>
<td>No.</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>-----</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>28</td>
<td>Mean Number of Frequent Species of Gulls and Terns per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>67</td>
</tr>
<tr>
<td>29</td>
<td>Mean Number of Frequent Species of Raptors per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320)</td>
<td>69</td>
</tr>
<tr>
<td>30</td>
<td>Total Annual Waterbird Use-Days per Five Hectares, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 1984-85 and 1985-86</td>
<td>71</td>
</tr>
<tr>
<td>31</td>
<td>Total Annual Shorebird, Gull and Tern Use-Days per Five Hectares, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 1984-85 and 1985-86</td>
<td>72</td>
</tr>
<tr>
<td>32</td>
<td>Fish-Eating Diver Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys)</td>
<td>73</td>
</tr>
<tr>
<td>33</td>
<td>Heron and Egret Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys)</td>
<td>75</td>
</tr>
<tr>
<td>34</td>
<td>Puddle Duck Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys)</td>
<td>77</td>
</tr>
<tr>
<td>35</td>
<td>Diving Duck Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys)</td>
<td>78</td>
</tr>
<tr>
<td>36</td>
<td>Coot and Rail Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys)</td>
<td>80</td>
</tr>
<tr>
<td>37</td>
<td>Large Shorebird Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys)</td>
<td>82</td>
</tr>
<tr>
<td>38</td>
<td>Small Shorebird Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys)</td>
<td>84</td>
</tr>
</tbody>
</table>
39  Gull and Tern Bird Use-Days per Five Hectares on High Tide Surveys
    on the Arcata Marsh and Wildlife Sanctuary, Humboldt County,
    California, 9 May 1984 - 21 August 1986
    (n = 320 High Tide Surveys) ............................................. 85

40  Raptor Bird Use-Days per Five Hectares on High Tide Surveys
    on the Arcata Marsh and Wildlife Sanctuary, Humboldt County,
    California, 9 May 1984 - 21 August 1986
    (n = 320 High Tide Surveys) ............................................. 87
INTRODUCTION

Nearly half of the original wetlands of the United States are estimated to have been lost (Costle 1978, Office of Technology Assessment 1984). In California it has been estimated that 52 percent of the coastal marshes, mud flats, bays, lagoons, sloughs and estuaries exclusive of San Francisco Bay have been destroyed by dredging and filling (Onuf et al 1978). Wetland destruction has not been isolated to California but in no other state has the loss been as great, amounting to 95 percent in some regions (Josselyn 1982a).

Society's concept of the value of wetlands has changed dramatically during the past three decades. Prior to 1950, the popular attitude was that wetlands were of little value except where they could be diked, drained, or filled to render them more adaptable to farming, grazing or real estate development for industrial, commercial or residential purposes (McCormick 1978). Wetlands are now viewed as valuable resources by political and economic circles as well as the scientific world (Odum 1978).

Governmental agencies have frequently had conflicting policies concerning wetlands (Madsen 1984, Weller 1987). The Soil Conservation Service, Army Corps of Engineers and Bureau of Land Management all have encouraged, subsidized or actually physically destroyed wetlands through agricultural practices and flood control projects (Weller 1987, Wentz 1988). The U.S. Fish and Wildlife Service has encouraged the preservation of wetlands, and leased or purchased them for waterfowl and other wildlife (Weller 1987). These conflicts were reduced in 1977 when the policies of these agencies were changed by Executive Order 11990 directing agencies to minimize wetland losses or degradation (Weller 1987). In spite of these improvements, many wetlands are still destroyed annually (Wetzel 1978, Office of Technology Assessment 1984, Wentz 1988).
Benefits produced by wetlands are received primarily by the general public rather than individual landowners. Private benefits of alternative uses for wetlands usually exceed private benefits from natural wetland values, leading to continued widespread destruction of private wetlands (Foster 1978, Madsen 1984, Wentz 1988). Because wetlands produce substantial public benefits, society has gradually moved to protect such areas by imposing increased government control of existing wetlands (Foster 1978, Wentz 1988), and restoring degraded wetlands and creating new ones (Josselyn 1982b).

Artificial wetlands, such as stockponds and dugouts for livestock have also been considered valuable wildlife habitat (Bue, Uhlig and Smith 1964). The importance of sewage oxidation ponds as wildlife habitat has received increased attention recently (Uhler 1964, Dodge and Low 1972, Tousley 1982, Belandger and Couture 1988). Uhler (1964) suggested that "wastelands" serve as important waterfowl habitats. One suggestion was to use nutrient-rich, treated wastewater to flood natural or man-made basins to stimulate growth of wildlife food and cover plants (Uhler 1964). Secondarily treated wastewater was used to convert Pintail Lake in Arizona from a sporadically and temporarily flooded basin to 19 hectares of permanent marsh (Piest and Sowls 1985). Piest and Sowls (1985) concluded that the use of sewage effluent to create wildlife habitat is a practical management technique.

The Arcata Marsh and Wildlife Sanctuary (Marsh Project) was one of the first man-made marsh systems built to combine the functions of wastewater reuse of domestic sewage effluent, a wildlife sanctuary, and an urban recreational area. Experimental applications of wastewater into marshes have shown promising results as a wastewater treatment (Kadlec 1978, Sloey et al. 1978, Environmental Protection Agency 1987). Wetlands appear to provide all of the biochemical transformations of wastewater constituents normally expected in conventional wastewater treatment plants (Bastian and Benforado 1988). When Arcata's wastewater treatment facility is fully
functional it is expected to produce an effluent meeting tertiary standards for non-filterable residue (NFR, suspended solids) and biochemical oxygen demand (BOD).

Friend (1981) stated:

The essential ingredient for wetlands is water, but unfortunately, the amount of water available is a finite quantity. In most instances, the use of water for wildlife is not an exclusive process, but instead represents a reuse from municipal, agricultural, or industrial sources. The question that must be considered is: How suitable is this water for waterfowl?

If the Marsh Project can be managed as a valuable wildlife habitat using treated, chlorinated-dechlorinated effluent this system may be applicable to many communities and we may begin to slowly replace some wetlands. Bastian and Benforado ((1988) stated:

Scientific uncertainties over the long-term benefits and detrimental effects of applying wastewater effluents to wetlands for treatment and / or reuse can only be clarified through more experience with operational systems. The possibilities for linking wastewater management with wetlands preservation or creation, non point water pollution control, ground-water recharge, stream flow stabilization, and wildlife habitat enhancement alone seem to be worth additional efforts.

The Arcata Marsh Project units were completed in 1980 and until July 1986, the main sources of fresh water for the marsh project was a groundwater well and water diverted from Jane's Creek. Both sources were available at the northeast corner of Gearheart Marsh. Water was pumped to either Gearheart or Allen Marsh and allowed to flow to other units by gravity flow through a series of stop log controls. Upgrading the wastewater treatment facilities and water control structures was completed by July 1986 and the first treated wastewater effluent began to flow into the units on 18 July 1986. The effluent first entered Allen Marsh directly from pipes and then flowed to the other two units before being pumped back to the chlorination facility from Hauser Marsh. The construction of new water control structures allow more control over water levels and flow patterns with the capability of draining or bypassing any one marsh unit individually (Hull 1988). Documentation of bird use and plant growth during the first year of flooding was completed by Spitler (1985).
In order to assess the value of the wastewater marsh habitat for wildlife a need arose to obtain baseline data from the established marshes prior to the introduction of wastewater effluent as the main fresh water source. This study was conducted to determine; (1) the general plant communities present and (2) the avifauna diversity and intensity of use during the two years immediately prior to the introduction of wastewater into the marshes. The data collected were used to determine general plant growth trends, seasonal patterns of bird use, differences in bird use between high and low tides on the adjacent Humboldt Bay, year to year fluctuations in bird use and differences in bird use among the marsh units. This study was conducted from 9 May 1984 to 21 August 1986.
STUDY AREA

The Marsh Project lies between the northeast shore of North Humboldt Bay and the southern fringe of Arcata, Humboldt County, California approximately 440 Kilometers (km) north of San Francisco Bay, California (Figure 1). This study was conducted on 37.8 ha of the Marsh Project including Klopp Lake, Gearheart, Allen and Hauser Marshes and an upland observation area (Figures 2, 3).

The site originally supported intertidal mudflats and salt marsh at the edge of Humboldt Bay. Starting in 1870, dikes and tide gates were built to hold back tidal waters, and to date 90 percent of the original salt marsh including most of the Marsh Project site has been "reclaimed" for non-wetland uses (Shapiro and Assoc. 1980, Glatzel 1982, Springer 1982). The Marsh Project units were used for a variety of purposes prior to construction of the marshes. A county landfill dump was operated in the area occupied by the observation area, Klopp Lake and Hauser Marsh. Allen Marsh was used for lumber storage and processing and Gearheart Marsh was pasture.

Uplands

The upland portion of the Marsh Project included approximately 11 ha of grassland and rank herbaceous habitats with scattered trees along the dikes, islands, and observation area (Figure 3).

Allen Marsh

Prior to construction in 1979 this 5.9 ha unit was an abandoned wood processing and storage facility covered with fill and woody debris (TerraScan 1979). Initial flooding took place in October 1980. By April 1981, the area supported a sparse cover of brass-buttons (*Cotula coronopifolia*) and cord grass (*Spartina densiflora*) (Spitler 1985). Between April 1981 and May 1984 the unit was filled and drained.
Figure 1. Location of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California.
Figure 2. Location of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California.
Figure 3. The Original 37.8 hectares of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, With the Original Water Sources and Flow Patterns and the Approximate Location of the Bird Survey Points and Area Surveyed.
several times in an attempt to flush tannins from the substrate but the unit remained dry most of the time (Hull Pers. Comm.).

Allen Marsh was nearly dry for most of this study because of a leaking stop-log control. In May 1984 the unit was dominated by upland grasses (Gramineae) and the islands and dikes supported mixtures of grasses, rank herbaceous vegetation and willows (Salix sp.). Brass-buttons was common along the borrow ditch and in low wet areas.

**Gearheart Marsh**

The 3.7 hectares occupied by Gearheart Marsh had been pasture prior to conversion to marshland. In April 1981 the most common aquatic plants were lesser duckweed (*Lemna minor*), common cattail (*Typha latifolia*), marsh pennywort (*Hydrocotyle ranunculoides*) and spikerush (*Eleocharis* sp.) (Spitler 1985). By May 1984 common cattail, marsh pennywort and sago pondweed (*Potamogeton pectinatus*) dominated the unit. There was no sign of wapato (*Sagittaria latifolia*) and only minimal stands of alkali bulrush (*Scirpus robustus*), species which had been planted in the unit on 18 February 1981 (Spitler 1985). Gearheart Marsh was flooded continuously from April 1981 throughout this study except for a temporary draw down from 6-13 October 1985. The average water depth of the unit was approximately 50 cm.

**Hauser Marsh**

Prior to construction, the 5.3 ha Hauser Marsh was an unfilled portion of the land fill dump site. After flooding aquatic vegetation invaded slowly and by April 1981 brass-buttons was the only aquatic species present (Spitler 1985). In early 1982 alkali bulrush and marsh pennywort were planted in Hauser Marsh (Hull pers. comm.). By May 1984 the unit was dominated by open water and contained only small patches of common cattail and alkali bulrush. During this study, Hauser Marsh was flooded except
During July-October 1985 when it was drained to accommodate the installation of pipes and control structures and to allow planting of hardstem bulrush (*Scirpus acutus*) in the southern quarter of the unit and in an east-west band approximately 10 meters wide near the center.

**Klopp Lake**

Klopp Lake was 11.9 ha including the dikes and islands. Freshwater entered Klopp Lake from Hauser Marsh from October 1980 until July 1985 when the stop log structure between the two units was removed (Figure 3). The lake also received backflow water at high tide from Humboldt Bay, resulting in a brackish water condition. In mid 1986 a ground water well was constructed at the north-west corner of the lake (Figure 4), but this well has since been disconnected. There are no plans to use the well unless a low-cost means of removing nitrates can be found (Hull pers. comm.). At present (1989) the main water sources for the lake are backflow tidal waters from Humboldt Bay and precipitation (Figure 4).
Figure 4. The Current Water Flow Patterns and Potential Water Sources of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California.
METHODS

Vegetation

Vegetation was monitored in two ways. Percent coverage of the marsh units was determined by preparing cover maps from low altitude aerial photographs and standing crop biomass was calculated by harvesting plant samples from random plots.

Cover maps were analyzed using a transparent grid overlay to determine the percent cover of the water surface area by the common plant species. Cover maps were prepared for all three marsh units in September 1987, but additional maps were prepared for Gearheart Marsh in April 1985 and September 1985 and for Allen Marsh in April 1986.

Peak standing crop biomass of the submergent vegetation was determined in Gearheart Marsh during 1985 and 1986 and in Hauser Marsh in 1986. Submergent vegetation was sampled in random plots using a modified Gerking sampler (30.48 x 30.48 cm square) (Gerking 1957). Random plots were determined using a transparent grid overlay on maps of the marsh units and randomly selecting coordinates using a random numbers table (Zar 1974). Plots that fell within stands of emergents or floating mat vegetation were not used for submergent plants. A total of 67 submergent plots was marked using a single redwood stake of a length so they emerged above the water surface by 15-20 cm. Fourty seven plots were located in Gearheart Marsh and 20 in Hauser Marsh. Only part of the plots marked in each marsh were sampled, because of time constraints, and the plots sampled were randomly selected from the original list of plots. Fourteen plots were sampled in 1985 in Gearheart Marsh and 24 were sampled in 1986. Fourteen plots were sampled in Hauser Marsh in 1986. Samples were collected 3-4 times during the growing season at approximately monthly intervals starting in May 1985 and in April 1986. The same plots were used during each sampling. Samples
were taken approximately one meter from the plot marker in a different compass direction each month starting with the northwest and moving around the plot marker in a clockwise direction for each subsequent sampling. Water depth was measured with a meter stick to the nearest 0.1 cm at each sampling site. "Deep water plots" were defined as those plots with water deeper than the mean for all plots for any sampling date, and "shallow water plots" were those plots with water depth less than the mean for all plots on each sampling date. Samples were rinsed thoroughly, oven dried at 105 degrees centigrade to a constant weight and weighed to the nearest .01 grams (Gerking 1957, Rich et al. 1971).

The area of each marsh unit and Klopp Lake used for unit to unit comparisons of bird use included the water surface area, dikes and islands and was taken from Spitler (1985).

**Bird Use**

**Survey Technique**

Diurnal waterbird use of each marsh unit was determined by direct counts of all birds on each unit. A 20 power spotting scope and 8.5x40 binoculars were used to aid counting and data were collected from three or four standardized stations (Davis and Winstead 1980, Spitler 1985) (Figure 3). Care was taken to avoid duplicating counts of birds between stations. Station data were summed to yield a total for each unit. At each station I scanned the observable surface and tallied all birds onto data sheets. Abundant species were scanned and tallied separately. Masses of shorebirds loafing on the islands in Klopp Lake were determined by counting a small area of the flock, estimating the percentage of each species present in the sample area and extrapolating that number to represent the number of each species in the total flock (Gerstengerg 1972, Spitler 1985). In the beginning, photographs were taken of flocks flushed from the islands. When
projected these images allowed me to count all birds present, forming a basis of comparison with the estimates made of the roosting birds.

An average of 2.4 surveys was conducted at high and also at low tide each week between 9 May 1984 and 21 August 1986 for a total of 320 high tide and 324 low tide surveys. Times of high and low tides were taken from published tide tables (Elliott Sales Corporation 1984, 1985, 1986). High tide surveys were conducted when the mud flats of the adjacent Humboldt Bay were 100 percent covered except during weeks when the highest tides of the week during daylight hours were too low to cover them (one or two weeks each year). During those weeks, surveys were conducted during the highest tides of the week. Low tide surveys were conducted when at least 40 percent of the mud flats were exposed.

Birds were grouped for analysis as follows:

1. Fish-Eating Divers (Loons, Grebes, Cormorants, and Pelicans)
2. Herons (Herons, Egrets and Bitterns)
3. Puddle Ducks (Swans, Geese and Surface feeding Ducks)
4. Diving Ducks (Sub-surface feeding Ducks)
5. Coots and Rails (Coots and Rails)
6. Large Shorebirds (Stilts, Avocets, Godwits, Plovers, Willits, Curlews, Knots, Turnstones, Snipe and Dowitchers)
7. Small Shorebirds (Small Sandpipers, Dunlins and Phalaropes)
8. Gulls and Terns (Gulls, Terns and Jaegers)
9. Raptors (Hawks, Falcons and Owls)

Whenever positive identification was not possible, birds were recorded to taxonomic groups as closely as possible, such as, large gull, small gull, small shorebird, scaup sp., etc. All Dowitchers were recorded as Dowitcher sp. Identification of birds was aided by Peterson (1961) and Scott (1983). Individual species analysis was limited to frequent species within each group. "Frequent" species of Raptors were defined as those recorded on ≥30 percent of the surveys throughout the study. "Frequent" species of all other groups were defined as those recorded on ≥40 percent of the surveys. Bird names follow American Ornithologist Union (1983).
Seasonal Use

Each year was divided into seven biological seasons, (52 to 53 days in length) corresponding to migration patterns of birds along the north coast of California (Gerstenberg 1972, Spitler 1985, Nelson 1989, Harris pers. comm.) as follows:

1. Summer (9 May - 30 June)
2. Early Fall (1 July - 21 August)
3. Mid Fall (22 August - 12 October)
4. Late Fall (13 October - 3 December)
5. Winter (4 December - 24 January)
6. Early Spring (25 January - 17 March)
7. Late Spring (18 March - 8 May)

Species recorded in large numbers on 95 percent or more of the surveys were considered "abundant". "Large numbers" were defined as more than 50 individuals of any species within all the bird groups except the gulls, large and small shorebirds where 100 individuals of each species had to be present to be considered "large numbers". "Common" species were those observed on more than 70 percent of the surveys. Species seen on 50 to 70 percent of the surveys were considered "fairly common". "Uncommon" species were those recorded on 10 to 50 percent of the surveys. "Rare" species were those recorded on less than 10 percent of the surveys.

Bird use-days were calculated using the high tide data. A mean was calculated for each week of the study, this mean was multiplied by seven to produce bird use-days per week. Seasonal bird use-days were calculated by summing all the weekly bird use-days within each season. Annual bird use-days were determined by summing all the weekly bird use-days within each year. Bird use-days refers to all species combined unless modified by a discriptive term, such as, fish-eating diver bird use-days. For brevity's sake the word "bird" has been left out in the text and just "use-days" often used with a discriptive term, such as, fish-eating diver use-days.

A non-parametric paired comparisons test (Wilcoxon's Signed-Ranks Test) was used to test for differences between high and low tides and between years (Sokal and Rolf 1981).
RESULTS

Vegetation

In Gearheart Marsh the coverage of common cattail nearly doubled between April 1985 and September 1987 while marsh pennywort nearly tripled (Table 1, Figure 5). Spikerush disappeared from Gearheart Marsh after September 1985 (Table 1, Figure 5). In September 1985 sago pondweed covered 77.2 percent of Gearheart Marsh. By September 1987, the sago beds were obscured by a mat of lesser duckweed and deep water (Table 1, Figure 5). The maximum coverage of the sago/duckweed stand in September could only have been 62.5 percent because of increases by common cattail and marsh pennywort (Table 1, Figure 5).

In September 1987, after a full year of reused wastewater as the main fresh water source, the vegetation in Hauser Marsh was dominated by lesser duckweed (Table 1, Figure 6).

Allen Marsh was transformed from a seasonal wetland dominated by upland grasses in April 1986 to a permanent marsh dominated by lesser duckweed and alkali bulrush by September 1987 (Table 1, Figure 7).

The peak sago pondweed standing crop present in Gearheart Marsh was measured in June 1985 (187.94 grams per square meter ± 113.08 g) and in June 1986 (132.77 grams per square meter ± 88.73 g). Mean sago pondweed standing crop was considerably less for plots in deep water (range = 52 - 92 cm and 54 - 80 cm in 1985 and 1986 respectively) compared to plots in shallow water (range = 36 - 65 cm and 36 - 53 cm in 1985 and 1986 respectively) during both years (Figures 8, 9).
Table 1. Percent Cover of the Dominant Plant Species at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California Calculated from Aerial Photographs 1985 - 1987.

<table>
<thead>
<tr>
<th>Cover Type</th>
<th>Gearheart Marsh</th>
<th>Hauser Marsh</th>
<th>Allen Marsh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Water</td>
<td>83.8</td>
<td>5.0</td>
<td>32.5*</td>
</tr>
<tr>
<td>Common Cattail</td>
<td>5.5</td>
<td>6.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Marsh Pennywort</td>
<td>10.0</td>
<td>11.8</td>
<td>27.0</td>
</tr>
<tr>
<td>Sago Pondweed</td>
<td>10.0</td>
<td>77.2</td>
<td>NV</td>
</tr>
<tr>
<td>Alkali Bulrush</td>
<td>0.8</td>
<td>0.8</td>
<td>NV</td>
</tr>
<tr>
<td>Lesser Duckweed</td>
<td>30.0*</td>
<td>69.6</td>
<td></td>
</tr>
<tr>
<td>Hardstem Bulrush</td>
<td>2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Spikerush</td>
<td>0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upland Grass sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Duckweed coverage is too low because the wind had pushed it into wind rows.
NV = Not Visible because of duckweed coverage.
Figure 5. Vegetation Cover of Gearheart Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California.
Figure 6. Vegetation Cover of Hauser Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, September 1987.
Figure 7. Vegetation Cover of Allen Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California.
Figure 8. Mean, Dry Weight, Standing Crop Biomass of Sago Pondweed For Gearheart Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California 1985. (Numbers in parentheses indicate water depth range in centimeters: \( n = \) number of plots sampled)
Figure 9. Mean, Dry Weight, Standing Crop Biomass of Sago Pondweed For Gearheart Marsh of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California 1986. (Numbers in parentheses indicate water depth range in centimeters: n = number of plots sampled)
Sago pondweed was not present in Hauser Marsh in 1985 because the unit was dry during the growing season (Figure 10) but in September 1986, there were 93.03(± 47.66) grams per square meter.

**Waterbird Use**

One hundred and seventy four species of birds were observed at the Marsh Project during this study. Of these, 98 species were observed on the water areas and are treated in this report (Appendix A).

**Effects of Tide Level**

Fish-eating divers frequented the Marsh Project about equally during high and low tides (Tables 2,3, Figure 11). Brown pelicans (*Pelecanus occidentalis*) and double-crested cormorants (*Phalacrocorax auritus*) both were present in significantly greater numbers (p< 0.05) at high tide (Tables 2, 3).

While herons and egrets (as a group) generally had no significant difference in use between high and low tide, great egrets (*Casmerodius albus*) and snowy egrets (*Egretta thula*) both were present in significantly greater numbers (p<0.05) at high tide (Tables 2, 3, Figure 12).

Puddle duck use of the marsh did not vary between high and low tide except that northern pintails (*Anas acuta*) were present in significantly greater numbers (p<0.05) at high tide and cinnamon teal (*Anas cyanoptera*) were found in significantly higher numbers at low tide in Hauser Marsh only (Tables 2, 3, Figure 13).

Diving duck use of the marsh was nearly equal between high and low tide generally, but ruddy ducks (*Oxyura jamaicensis*) were present in Klopp Lake in significantly greater numbers (p<0.05) at low tide (Tables 2, 3, Figure 14).

Coots and rails exhibited no significant difference in use of the Marsh Project between high and low tide (Tables 2, 3, Figure 15).
Figure 10. Approximate Water Level Deviations from the Operating Level, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California. SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Table 2. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1964 and 9 May 1985 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses).

<table>
<thead>
<tr>
<th>Region</th>
<th>Marsh Unit</th>
<th>Season</th>
<th>HT (19)</th>
<th>LT (19)</th>
<th>HT (20)</th>
<th>LT (20)</th>
<th>HT (18)</th>
<th>LT (18)</th>
<th>HT (21)</th>
<th>LT (21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red-tailed Gulls</td>
<td>Kelpy Lake</td>
<td>Summer</td>
<td>0.1 0.1</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Early Fall</td>
<td>0.1 0.1</td>
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<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
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<td>0.0 0.0</td>
<td>0.0 0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mid Fall</td>
<td>0.7 0.7</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Late Fall</td>
<td>0.7 0.7</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
<td>0.0 0.0</td>
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<tr>
<td></td>
<td></td>
<td>Winter</td>
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Table 2. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1984 and 9 May 1985 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

<table>
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<tr>
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<th>Marsh Unit</th>
<th>Summer Mean</th>
<th>Winter Mean</th>
<th>Spring Mean</th>
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<tr>
<td></td>
<td>HT (18)</td>
<td>LT (19)</td>
<td>HT (23)</td>
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<tr>
<td>Black-crowned Night Heron</td>
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<td>American Bittern</td>
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<tr>
<td>Caspian Tern</td>
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<tr>
<td>Total Herons</td>
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</tr>
<tr>
<td>Total Egrets</td>
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<tr>
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</tr>
<tr>
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<tr>
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Note: HT = High Tide, LT = Low Tide.
<table>
<thead>
<tr>
<th>Species</th>
<th>Month Unit</th>
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<th>Mid Fall</th>
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<th>Winter</th>
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<td></td>
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<tr>
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</tr>
<tr>
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<td>0.0</td>
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</tr>
<tr>
<td>Lesser Scaup</td>
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Table 2. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1984 and 9 May 1985 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)
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*HT = High Tide; LT = Low Tide; NS = Not Specified

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Table 2. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1984 and 9 May 1985 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

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Table 2. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1984 and 9 May 1985 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

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<th>Winter (16)</th>
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Tr denotes trace (<0.1 birds per survey per season).
NT denotes too rare to test (present in five or less seasons).
NS denotes no significant difference between high tide (HT) and at low tide (LT).
*HT denotes a significant difference (p<0.05, more birds at high tide) between the number of birds recorded at high tide (100% mud flats covered) and at low tide (>60% mud flats covered).
*Lt denotes a significant difference (p<0.05, more birds at low tide) between the number of birds recorded at high tide (100% mud flats covered) and at low tide (60% mud flats covered).
** Seasonal Periods are: Summer (9 May - 30 June); Early Fall (1 July - 21 August); Mid Fall (22 August - 12 October); Late Fall (13 October - 3 December); Winter (4 December - 24 January); Early Spring (25 January - 17 March); Late Spring (18 March - 8 May).
Table 3. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses).

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Notes: Summer = May 1985 to August 1986; Winter = September 1985 to April 1986; Fall = April 1986 to May 1986.
Table 3. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

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**Note:** The table continues with data for other bird species across different seasons and tides. It includes columns for HT and LT with corresponding survey numbers in parentheses.
<p>| Species             | Marsh Unit | Signif. | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring | Summer | Early Fall | Late Fall | Winter | Early Spring | Late Spring |
|---------------------|------------|---------|---------|-----------|-----------|--------|-----------|-----------|---------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|--------|-----------|-----------|</p>
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Table 3. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)
Table 3. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

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<td>$^{f}$</td>
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Notes: ** (Continued)
Table 3. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

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Table 3. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

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Table 3. Mean Number of Birds Recorded per Survey on the Marsh Units of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, Between 9 May 1985 and 21 August 1986 at High Tide (HT) and at Low Tide (LT) (number of surveys in parentheses). (Continued)

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<td>*HT denotes a significant difference (p&lt;0.05, more birds at high tide) between the number of birds recorded at high tide (100% mud flat covered) and at low tide (≤ 60% mud flat covered).</td>
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| ** Seasonal Periods are: Summer (9 May - 30 June); Early Fall (1 July - 31 August); Mid Fall (22 August - 20 December); Late Fall (21 December - 31 January); Winter (1 February - 31 March); Early Spring (1 April - 30 June); Late Spring (1 July - 30 August).
Figure 11. Mean Number of Fish Eating Divers per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 12. Mean Number of Herons and Egrets per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 13. Mean Number of Puddle Ducks per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 14. Mean Number of Diving Ducks per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 15. Mean Number of Coots and Rails per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
All shorebirds were present in significantly greater numbers (p<0.05) during high tide surveys than at low tide surveys except black-necked stilts (*Himantopus mexicanus*), spotted sandpipers (*Actitis macularia*), common snipe (*Gallinago gallinago*) and lesser yellowlegs (*Tringa flavipes*) which showed no significant differences (Tables 2, 3; Figures 16, 17).

All of the gulls and terns tested statistically were present in significantly greater numbers (p<0.05) at high tide (Tables 2, 3, Figure 18).

Raptor use of the marsh was generally similar between high and low tide throughout the study period (Figure 19). Peregrine falcons (*Falco peregrinus*) and northern harriers (*Circus cyaneus*) were significantly more numerous (p<0.05) at high tide than at low tide on a marsh wide basis and black-shouldered kites (*Elanus caeruleus*) and american kestrels (*Falco sparverius*) were significantly more numerous (p<0.05) at low tide than at high tide in Allen Marsh only (Tables 2, 3).

Because most of the waterbird species using the Marsh Project had no significant difference in use between tide levels or were found in significantly greater numbers at high tide than at low tide, all remaining analysis of waterbird use was based only on the 320 high tide surveys.

**Seasonal Use**

Peak waterbird use occurred during winter, early and late spring in both years with 63.1 and 61.0 percent of the annual total bird use-days represented in those three seasons in 1984-85 and 1985-86 respectively (Table 4, Figure 20). The lowest waterbird use occurred in summer with 0.48 and 0.42 percent of the total annual bird use-days in 1984-85 and 1985-86 respectively.
Figure 16. Mean Number of Large Shorebirds per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 17. Mean Number of Small Shorebirds per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 18. Mean Number of Gulls and Terns per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 19. Mean Number of Raptors per Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide and 324 Low Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Table 4. Frequent Species Bird Use-Days per Season and Percent of Annual Total Bird Use-days, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986.

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<th>Mid Fall</th>
<th>Late Fall</th>
<th>Winter</th>
<th>Early Spring</th>
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- **Great Blue**: 84-85 21.6 7.3 51.9 17.6 77.0 26.1 63.0 21.4 43.2 14.7 28.6 9.7 9.3 3.2 294.6
- **Heron**: 85-86 33.8 18.0 22.3 17.8 45.3 31.4 53.3 16.1 46.7 24.8 19.8 10.6 11.7 6.3 187.8
- **Great Egret**: 84-85 143.8 21.9 160.4 25.6 107.0 15.8 72.3 10.7 67.7 10.0 72.3 10.7 50.2 7.4 678.5
- **Earing Egret**: 85-86 328.7 14.3 333.7 17.2 71.2 7.9 156.5 16.8 103.0 11.7 23.3 2.6 84.0 9.4 986.0
- **Snowy Egret**: 84-85 151.4 3.8 357.2 19.7 492.3 28.7 282.3 16.5 248.3 14.2 167.4 9.8 40.8 2.4 1715.4
- **Other Herons**: 85-86 291.7 13.7 336.4 15.8 476.0 22.4 466.0 19.1 253.5 12.0 261.3 13.3 96.8 4.6 2123.9
- **Earing Dives**: 86 190.8 33.5 444.5 14.0 492.3 28.7 282.3 16.5 248.3 14.2 167.4 9.8 40.8 2.4 1715.4
- **Total Herons** and **Eaglets**: 85-86 336.7 11.1 671.4 22.1 788.7 26.0 435.2 14.3 388.5 12.8 294.6 9.7 122.5 4.0 3837.5
- **Mallard**: 85-86 688.3 17.6 856.3 21.7 611.3 15.5 603.2 15.3 632.3 16.0 351.2 8.9 199.5 5.1 3942.2
- **Cinnamon Teal**: 86 525.6 1190.0
- **Green-winged Teal**: 85-86 1316.0 16.7 2826.3 23.0 2188.7 17.8 1234.3 10.1 2254.0 18.4 1409.3 11.5 1036.0 8.4 12264.6
- **Dark-eyed Juncos**: 85-86 1436.2 6.9 1106.0 5.3 5129.8 24.5 5027.2 24.1 6156.5 29.5 1471.2 7.0 569.3 2.7 20896.2
- **Double-crested Cormorant**: 85-86 984.7 1351.0
- **Earing Dives**: 86 208.7 2.9 1430.3 19.8 1348.7 18.7 862.2 11.9 1199.3 16.6 1202.8 16.7 965.4 13.4 7217.5
- **Total Paddle** **Duck**: 85-86 1026.7 12.2 1713.1 13.9 2126.8 25.3 1629.8 19.4 1037.2 12.3 924.0 11.0 491.2 5.8 8407.0
- **Total Paddle** **Eaglets**: 85-86 1171.9 1421.0
- **Earing Dives**: 86 884.0 4.3 455.1 15.5 581.0 18.7 222.8 7.2 1338.2 43.1 681.3 22.0 225.8 7.3 3103.0
- **Total Paddle** **Eaglets**: 85-86 222.2 0.1 47.6 0.0 844.7 10.3 604.3 7.4 432.5 52.9 2238.8 27.4 154.6 1.9 8164.9
- **Green-winged Teal**: 86 7.6 2.3
- **Total Paddle** **Eaglets**: 85-86 2456.8 21.0 1341.2 23.3 2596.0 42.8 4554.8 8.2 2495.5 4.1 4644.1.9
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Table 4. Frequent Species Bird Use-Days per Season and Percent of Annual Total Bird Use-days, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986. (Continued)

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Table 4. Frequent Species Bird Use-Days per Season and Percent of Annual Total Bird Use-days, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986. (Continued)

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<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BUD</td>
<td>%</td>
<td>BUD</td>
<td>%</td>
<td>BUD</td>
<td>%</td>
<td>BUD</td>
<td>BUD</td>
</tr>
<tr>
<td>Total Water Birds</td>
<td>84-85</td>
<td>6339.0</td>
<td>0.48</td>
<td>80666.9</td>
<td>5.62</td>
<td>191592</td>
<td>13.35</td>
<td>249862</td>
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<tr>
<td></td>
<td></td>
<td>85-86</td>
<td>6010.4</td>
<td>0.42</td>
<td>154744.0</td>
<td>10.82</td>
<td>169819.0</td>
<td>11.89</td>
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<tr>
<td></td>
<td></td>
<td>86</td>
<td>6552.8</td>
<td></td>
<td>81578.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Seasonal Periods are: Summer (9 May - 30 June); Early Fall (1 July - 21 August); Mid Fall (22 August - 12 October); Late Fall (13 October - 3 December); Winter (4 December - 24 January); Early Spring (25 January - 17 March); Late Spring (18 March - 8 May).

BUD = Bird Use-days.
Figure 20. Bird Use-Days at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, by Bird Group, 9 May 1984 - 21 August 1986. (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Shorebirds represented 87.9 percent of all bird use-days throughout this study while waterfowl and coots and rails accounted for 8.8 percent (Table 4, Figure 20). Small shorebirds were the single most numerous bird group and represented over 40 percent of the total bird use-days (Table 4, Figure 20).

Fish-eating diver use of the Marsh Project was distinctly seasonal (Figure 21). The highest use occurred between late fall and early spring in both years (72.3 percent and 76.9 percent of the yearly total use respectively), (Table 4).

Although herons and egrets were present all year, peak numbers occurred from summer to late fall (73.5 percent in 1984-85; 70.0 percent 1985-86), (Table 4). Heron and egret use declined in winter and spring each year (Figure 22). Snowy egrets accounted for 33.3 to 77.9 percent of all heron and egret use-days (Table 4, Figure 22). Great egrets, the second most numerous heron, accounted for 6.6 to 44.0 percent of the total heron and egret use-days (Table 4, Figure 22).

Puddle ducks exhibited distinct seasonal fluctuations with peak numbers in winter each year (Table 4, Figure 23). Lowest numbers of puddle ducks consistently occurred during summer and early fall when nesting mallards (*Anas platyrhynchos*) and cinnamon teal constituted between 98.1 and 99.6 percent of all puddle ducks observed (Table 4, Figure 23). In both winters green-winged teal (*Anas crecca*) accounted for 47.4 and 64.3 percent of all puddle duck use-days (Table 4, Figure 23).

The diving duck group exhibited very consistent seasonal use patterns with first fall migrants arriving in late fall, peak numbers during winter and near total departure by spring (Table 4, Figure 24). In 1984-85 ruddy ducks accounted for 69.6 percent of the total diving duck use (Table 4, Figure 24). In 1985-86, lesser scaup (*Aythya affinis*) accounted for 40.4 percent and ruddy ducks for 27.9 percent of all diving duck use-days (Table 4, Figure 24).

Coots and rails were present in peak numbers from late fall to winter in both years with 65.1 and 77.7 percent of the coot and rail use-days occurring in those two
Figure 21. Mean Number of Frequent Species of Fish Eating Divers per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 22. Mean Number of Frequent Species of Herons and Egrets per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 23. Mean Number of Frequent Species of Puddle Ducks per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 24. Mean Number of Frequent Species of Diving Ducks per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
seasons in each year respectively (Table 4, Figure 25). Use in summer and early fall was generally low in both years (1.4 and 0.8 percent respectively), (Table 4, Figure 25). American coots (*Fulica americana*) constituted an average of 99.2 percent (seasonal range 94.7 to 100) of all coot and rail use-days (Table 4).

As a group, large shorebirds were nearly absent during summer (0.2 and 0.1 percent of the yearly total large shorebird use-days in 1984-85 and 1985-86 respectively), (Table 4, Figure 26). Populations built up in early fall and generally remained high through winter, declining in late spring (Table 4, Figure 26).

Within the large shorebird group marbled godwits were consistently most numerous representing an average of 50.3 percent (seasonal range 0.0-74.1) of the seasonal large shorebird use-days throughout the study (Table 4, Figure 26). Marbled godwits arrived during early fall and peaked during winter and early spring (Table 4, Figure 26). American avocets, the second most numerous large shorebirds contributed 14.4 (1984-85) and 15.3 (1985-86) percent of the yearly total large shorebird use-days (Table 4, Figure 26). American avocets arrived in early fall and built up to their peak in winter with 80.1 and 82.9 percent of avocet use-days occurring from mid fall to early spring in 1984-85 and 1985-86 respectively (Table 4, Figure 26). Avocet numbers dropped to nearly zero by summer (Table 4, Figure 26). Black-bellied plovers (*Pluvialis squatarola*) and dowitchers spp. contributed 10.8 and 9.9 percent of the large shorebird use-days respectively between summer 1984 and late spring 1986 (Table 4, Figure 26). Both black-bellied plovers and dowitchers spp. exhibited two peaks during each year arriving in early fall, reaching peaks between mid fall and late fall, declining during winter and peaking again in early or late spring (Figure 26). Willets were the least numerous of the frequent species of large shorebirds and they were present for the shortest time each year arriving in mid fall and leaving during late spring (Figure 26).

Small shorebirds were absent during summer each year and the first fall migrants arrived in early fall (Figure 27). The peak numbers occurred during late spring
Figure 25. Mean Number of Frequent Species of Coots and Rails per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 26. Mean Number of Frequent Species of Large Shorebirds per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 27. Mean Number of Frequent Species of Small Shorebirds per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
in both years with 56.3 and 48.9 percent of all small shorebird use-days occurring during early and late spring in 1984-85 and 1985-86 respectively (Table 4, Figure 27).

Least sandpipers (Calidris minutilla) were the least numerous of the small shorebirds accounting for an average of 8.1 percent of the total small shorebird use-days per season with a range of 0.0 to 37.3 percent for the entire study (Table 4). Least sandpipers peak use was during mid fall in both years. Dunlins (Calidris alpina) represented 67.8 and 46.9 percent of the yearly total small shorebird use-days in 1984-85 and 1985-86 respectively (Table 4). Dunlins arrived each year near the end of mid fall (Table 4). Dunlin peak use occurred in late spring in 1984-85 and in late fall in 1985-86 (Table 4, Figure 27). Western sandpipers (Calidris mauri) accounted for 28.5 and 51.0 percent of the yearly total small shorebird use-days in 1984-85 and 1985-86 respectively (Table 4). Western sandpipers arrived during early fall and exhibited two peaks in use each year (Table 4, Figure 27). The first peak was from early fall to late fall and the second peak was in late spring when 36.8 (1984-85) and 44.0 (1985-86) percent of the western sandpiper use-days occurred (Table 4, Figure 27).

Gulls and terns were present all year but were least numerous in summer each year (Table 4, Figure 28). Gulls and terns generally were most numerous in fall and winter (Table 4, Figure 28).

Among the gull and tern group, ring-billed gulls (Larus delawarensis) accounted for 45.5 and 52.2 percent of the yearly total gull and tern use-days in 1984-85 and 1985-86 respectively (Table 4, Figure 28). Western gulls (L. occidentalis) were consistently the second most numerous species of gulls and terns representing 20.3 and 18.4 percent of the yearly total gull and tern use-days in 1984-85 and 1985-86 respectively (Table 4, Figure 28). Western gulls were present all year but they were least numerous in late spring and summer and peaked from mid fall to winter in each year (Table 4, Figure 28). During 1984-85 an average of 81.4 mew gulls was present
Figure 28. Mean Number of Frequent Species of Gulls and Terns per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
per survey in winter and 164.5 in early spring (Table 2). Glaucous-winged gulls (L. glaucescens) were consistently found in the lowest numbers among the frequent species of gulls and terns and represented 6.2 and 12.5 percent of the yearly total gull and tern use-days in 1984-85 and 1985-86 respectively (Table 4, Figure 28).

Raptors were found in peak numbers during late fall and winter in both years with 53.5 and 51.1 percent of the yearly total raptor use-days occurring during those two seasons in 1984-85 and 1985-86 respectively (Table 4, Figure 29). Raptors were present all year and the low use periods varied from late spring, summer and early fall (Table 4, Figure 29).

The frequent species of raptors were northern harriers, black-shouldered kites and red-tailed hawks (Buteo jamaicensis) with 23.9, 23.5 and 13.5 percent of the total raptor use-days respectively (Table 4, Figure 29).

Waterbird Use Among Marsh Units and Between Years

The total waterbird use-days was 1,434,633 in 1984-85 and 1,429,873 in 1985-86. For direct comparisons among marsh units simple bird use-days were converted to bird use-days per five hectares (Table 5). Klopp Lake had the highest percentage of the total bird use-days per five hectares in both years because of large and small shorebird use (Table 5; Figures 30, 31). Gearheart Marsh was second and Hauser Marsh was third in percentage of total bird use-days per five hectares in both years because of puddle ducks, coots and diving ducks in Gearheart and coots and small shorebirds in Hauser Marsh (Table 5; Figures 30, 31).

Fish-eating divers were significantly fewer in number of bird use-days per five hectares (p<0.05) in Klopp Lake, Allen Marsh and the Marsh Project as a whole in 1985-86 when compared to 1984-85 (Table 5). The main difference in fish-eating diver use between the two years was a reduction in numbers of double-crested cormorants and other fish-eating divers in Klopp Lake in 1985-86 (Figure 32).
Figure 29. Mean Number of Frequent Species of Raptors per High Tide Survey on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, May 1984 - September 1986 (n=320). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Table 5. Annual Bird Use-Days per Five Hectares Within Each Marsh Unit at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 1984-85 and 1985-86.

<table>
<thead>
<tr>
<th>Bird Group</th>
<th>Gearhart Marsh</th>
<th>Hauser Marsh</th>
<th>Allen Marsh</th>
<th>Klooo Lake</th>
<th>Total Sanctuary</th>
</tr>
</thead>
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<tr>
<td></td>
<td>1984-85 BUDS/Ha</td>
<td>1985-86 BUDS/Ha</td>
<td>1984-85 BUDS/Ha</td>
<td>1985-86 BUDS/Ha</td>
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<td>Fish Eating Divers</td>
<td>1670 NS</td>
<td>1700</td>
<td>610 NS</td>
<td>828</td>
<td>117 **</td>
</tr>
<tr>
<td>% of Unit Total</td>
<td>3.51 1.83</td>
<td>1.31 1.30</td>
<td>0.70 0.21</td>
<td>0.25 0.13</td>
<td>0.37 0.27</td>
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<tr>
<td>Herons and Egrets</td>
<td>803 **</td>
<td>2813</td>
<td>806 **</td>
<td>385 **</td>
<td>764 NS</td>
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<tr>
<td>% of Unit Total</td>
<td>1.69 3.02</td>
<td>1.73 0.60</td>
<td>4.60 2.10</td>
<td>0.05 0.08</td>
<td>0.21 0.28</td>
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<td>Paddle Ducks</td>
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<td>63360</td>
<td>6126 **</td>
<td>1018 **</td>
<td>8120 NS</td>
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<td>% of Unit Total</td>
<td>37.69 68.11</td>
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<td>48.91 54.46</td>
<td>0.10 0.03</td>
<td>2.14 4.24</td>
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<td>Diving Ducks</td>
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<td>7451</td>
<td>6892 **</td>
<td>2461 **</td>
<td>604 NS</td>
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<td>% of Unit Total</td>
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<td>14.80 3.86</td>
<td>3.64 3.81</td>
<td>2.06 4.13</td>
<td>3.10 4.30</td>
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<td>Coots and Rails</td>
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<td>14605</td>
<td>18411 **</td>
<td>2113 **</td>
<td>4109 NS</td>
</tr>
<tr>
<td>% of Unit Total</td>
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<td>39.53 3.31</td>
<td>24.75 17.72</td>
<td>0.33 2.13</td>
<td>2.73 3.08</td>
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<td>11442 NS</td>
<td>14759</td>
<td>1158 NS</td>
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<td>% of Unit Total</td>
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<td>24.57 23.14</td>
<td>6.97 17.58</td>
<td>46.18 40.13</td>
<td>43.77 37.20</td>
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<td>Small Shorebirds</td>
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<td>18</td>
<td>2197 **</td>
<td>41919 **</td>
<td>1529 NS</td>
</tr>
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<td>% of Unit Total</td>
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<td>4.72 65.72</td>
<td>9.21 2.41</td>
<td>46.52 51.2</td>
<td>43.47 48.64</td>
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<td>Gulls and Terns</td>
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<td>54 NS</td>
<td>262</td>
<td>2 NS</td>
</tr>
<tr>
<td>% of Unit Total</td>
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<td>0.12 0.41</td>
<td>0.01 0.00</td>
<td>4.47 2.20</td>
<td>4.15 1.94</td>
</tr>
<tr>
<td>Raptors</td>
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<td>60</td>
<td>38 NS</td>
<td>40 **</td>
<td>202 **</td>
</tr>
<tr>
<td>% of Unit Total</td>
<td>0.14 0.06</td>
<td>0.08 0.06</td>
<td>1.22 1.72</td>
<td>0.02 0.02</td>
<td>0.04 0.05</td>
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<td>46575</td>
<td>63784</td>
<td>16603</td>
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NS = Not Significant
NT = Not Testable
** = Significant Difference at p<.05
Figure 30. Total Annual Waterbird Use-Days per Five Hectares, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 1984-85 and 1985-86.
Figure 31. Total Annual Shorebird, Gull and Tern Use-Days per Five Hectares, Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 1984-85 and 1985-86.
Figure 32. Fish-Eating Diver Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Gearheart Marsh was used at a higher rate than other units by fish-eating divers (more than half of all fish-eating diver use-days per five ha) in 1985-86 (Table 5; Figures 30, 32). Gearheart Marsh was used by five species of fish-eating divers but pied-billed grebes (*Podilymbus podiceps*) were most numerous (Tables 2, 3; Figures 21, 30). All 11 species of fish-eating divers used Klopp Lake, six species used Hauser Marsh and only pied-billed grebes and double-crested cormorants used Allen Marsh (Tables 2, 3). Fewer fish-eating divers used Allen Marsh than the other units (Table 5; Figures 30, 32).

Fish-eating divers accounted for less than one percent of the total use-days per five hectares for the entire marsh during both years (Table 5, Figure 30).

Heron and egret rate of use was highest in Hauser and Gearheart Marshes in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 33). Their rate of use was lowest in Klopp Lake during 1984-85 and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 33).

All eight species of herons and egrets used Gearheart Marsh, seven species were found in Allen Marsh with six species in each of Hauser Marsh and Klopp Lake (Tables 2, 3).

Heron and egret rate of use was highest in Hauser and Gearheart Marshes in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 33). Their rate of use was lowest in Klopp Lake during 1984-85 and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 33).

All eight species of herons and egrets used Gearheart Marsh, seven species were found in Allen Marsh with six species in each of Hauser Marsh and Klopp Lake (Tables 2, 3).

Heron and egret rate of use was highest in Hauser and Gearheart Marshes in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 33). Their rate of use was lowest in Klopp Lake during 1984-85 and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 33).

All eight species of herons and egrets used Gearheart Marsh, seven species were found in Allen Marsh with six species in each of Hauser Marsh and Klopp Lake (Tables 2, 3).

Heron and egret rate of use was highest in Hauser and Gearheart Marshes in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 33). Their rate of use was lowest in Klopp Lake during 1984-85 and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 33).

All eight species of herons and egrets used Gearheart Marsh, seven species were found in Allen Marsh with six species in each of Hauser Marsh and Klopp Lake (Tables 2, 3).

Heron and egret rate of use was highest in Hauser and Gearheart Marshes in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 33). Their rate of use was lowest in Klopp Lake during 1984-85 and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 33).

All eight species of herons and egrets used Gearheart Marsh, seven species were found in Allen Marsh with six species in each of Hauser Marsh and Klopp Lake (Tables 2, 3).

Heron and egret rate of use was highest in Hauser and Gearheart Marshes in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 33). Their rate of use was lowest in Klopp Lake during 1984-85 and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 33).

All eight species of herons and egrets used Gearheart Marsh, seven species were found in Allen Marsh with six species in each of Hauser Marsh and Klopp Lake (Tables 2, 3).

Heron and egret rate of use was highest in Hauser and Gearheart Marshes in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 33). Their rate of use was lowest in Klopp Lake during 1984-85 and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 33).

All eight species of herons and egrets used Gearheart Marsh, seven species were found in Allen Marsh with six species in each of Hauser Marsh and Klopp Lake (Tables 2, 3).
Figure 33. Heron and Egret Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Puddle ducks significantly increased (p<0.05) in bird use-days throughout the marsh as a whole between 1984-85 and 1985-86 (Tables 4, 5, Figure 34). Puddle ducks increased significantly (p<0.05) in bird use-days per five hectares in Gearheart Marsh (71.7 percent increase) from 1984-85 to 1985-86 while in Hauser Marsh they decreased significantly (p<0.05) by 83.4 percent (Table 5; Figures 30, 34).

Puddle ducks used Gearheart Marsh at the highest rate per five ha during both years (Table 5; Figures 30, 34). Allen Marsh was used at the second highest rate per five hectares in both years with most of the use occurring from winter to early spring each year (Table 5; Figures 30, 34). Hauser Marsh was used at the third highest rate in both years with most of the use occurring in early to late fall in 1984-85 and in summer during 1985-86 (Table 5; Figures 30, 34).

Ten of the 12 species of puddle ducks observed on the Marsh Project during this study were seen in Gearheart Marsh, nine were found in Hauser Marsh, seven in Klopp Lake and six in Allen Marsh (Tables 2, 3).

On an area basis, the puddle duck group was more abundant than other groups in Gearheart and Allen Marshes during both years (Table 5; Figures 30, 31). Puddle ducks were third in abundance in Hauser Marsh during 1984-85 but fell to fifth in Hauser in 1985-86 (Table 5; Figures 30, 31). They were sixth and fourth respectively in 1984-85 and 1985-86 on the Marsh Project as a whole (Table 5).

Diving duck use-days increased at the Marsh Project by 28 percent from 1984-85 to 1985-86 (Tables 4, 5). Diving ducks significantly decreased (p<0.05) in Gearheart and Hauser Marshes between 1984-85 and 1985-86 with reductions of 39 and 67 percent respectively (Table 5; Figures 30, 35). Diving ducks increased by 47.7 percent in Klopp Lake but the increase was not statistically significant (Table 5; Figures 30, 35).

The diving duck use rate per five ha was highest in Gearheart Marsh and second highest in Klopp Lake in 1984-85 (Table 5, Figure 30). In 1985-86, Klopp
Figure 34. Puddle Duck Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 35. Diving Duck Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Lake had a mean of more than 500 diving ducks per day all winter (Table 3) resulting in far higher diving duck use-days per five hectares than any other unit (Table 5; Figures 30, 35).

All 16 species of diving ducks observed on the Marsh Project during this study were recorded on Klopp Lake, 13 of the 16 were found on Hauser Marsh, nine were present in Gearheart Marsh and eight in Allen Marsh (Tables 2, 3).

Diving ducks represented three to four percent of the yearly total bird use of the entire Marsh Project during both years (Table 5). They ranked fourth and third in percentage of the total annual bird use-days by bird groups for the entire Marsh Project during 1984-85 and 1985-86 respectively (Tables 4, 5; Figures 30, 31). They were the third highest among bird group bird use-days in Gearheart and Hauser Marshes in both years (Table 5; Figures 30, 31). Diving ducks were fourth in 1984-85 and third in 1985-86 in bird use-days among bird groups in Klopp Lake (Table 5; Figures 30, 31). In Allen Marsh they ranked sixth in 1984-85 and fourth in 1985-86 (Table 5; Figures 30, 31).

Coot and rail use-days increased by 11.2 percent between 1984-85 and 1985-86 for the Marsh Project as a whole (Tables 4, 5). Coots and rails decreased significantly (p<0.05) (by 88.5 percent) in Hauser Marsh and increased significantly (p<0.05) in Klopp Lake (by 83.8 percent) between 1984-85 and 1985-86 (Table 5; Figures 30, 36).

Coot and rail use rate per five hectares was highest in Hauser Marsh in 1984-85 and in Gearheart Marsh in 1985-86 (Table 5; Figures 30, 36). Gearheart Marsh had the second highest coot and rail use-days per five hectares in 1984-85 and Klopp Lake was second in 1985-86 (Table 5; Figures 30, 36). Allen Marsh was third in coot and rail use-days per five hectares in both years (Table 5; Figures 30, 36).
Figure 36. Coot and Rail Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Allen and Gearheart Marshes were the only units where all three species of coot and rails were observed (Tables 2, 3). Klopp Lake and Hauser Marsh each had two species during this study (Tables 2, 3).

Coots and rails represented about three percent of the total bird use-days at the Marsh Project during the study but within the individual marsh units they ranged from 0.33 percent to 39.53 percent (Table 5; Figures 30, 36). Coots and rails ranked fifth in percentage of total annual bird use-days among bird groups both years (Table 5). Within Hauser Marsh, coots and rails were the most numerous bird group during 1984-85 but dropped to fourth in 1985-86 (Table 5; Figures 30, 31). Coots and rails ranked second among bird groups in Allen and Gearheart Marshes during both years (Table 5; Figures 30, 31). In Klopp Lake they ranked fifth both years (Table 5; Figures 30, 31).

Marsh Project use by large shorebirds decreased significantly (p<0.05) from 1984-85 to 1985-86 as they decreased by 16.3 percent for the entire Marsh Project (Tables 4, 5; Figure 37). There was a significant decrease (p<0.05) of 17 percent in use of Klopp Lake (Table 5; Figures 31, 37).

More than 14 times as many large shorebird use-days per five hectares were recorded in Klopp Lake than in the other units in both years with Hauser Marsh receiving most of the remaining use (Table 5; Figures 31, 37). Hauser Marsh received sporadic use during the study from early fall to late spring (Figure 37).

Eighteen of the 19 large shorebird species observed on the Marsh Project during the study were recorded on Klopp Lake, 13 species were observed on Hauser Marsh, ten on Allen Marsh and seven on Gearheart Marsh (Tables 2, 3).

Large shorebirds were the most numerous bird group in 1984-85 and second most numerous in 1985-86 for the entire Marsh Project (Table 5). Over one third of all bird use-days on Klopp Lake were large shorebirds during both years ranking them second in numbers of annual bird use-days among bird groups in both years (Tables 4, 5; Figures 30, 31). One quarter of the bird use-days on Hauser Marsh were large
Figure 37. Large Shorebird Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
shorebirds in both years making that group the second most numerous in this marsh unit each year (Table 5; Figures 30, 31).

Small shorebird use increased significantly (p<.05) by 94.8 percent in Hauser Marsh between 1984-85 and 1985-86 (Table 5; Figures 31, 38). Small shorebird use increased by 10.3 percent for the Marsh Project and by 4.9 percent in Klopp Lake between 1984-85 and 1985-86 but neither increase was statistically significant (Table 5). Nearly all of the increase was contributed by Western Sandpipers during late spring (Figure 27).

More than six times as many small shorebird use-days per five hectares were recorded in Klopp Lake than in the other units combined in both years with Hauser Marsh receiving most of the remaining use (Table 5; Figures 31, 38).

All nine small shorebird species observed at the Marsh Project during this study were recorded on Hauser Marsh, seven species were found on Allen Marsh, six species on Gearheart Marsh and five species in Klopp Lake (Tables 2, 3).

Small shorebirds were the most numerous bird group on the entire Marsh Project during 1985-86 accounting for nearly 45 percent of all bird use-days and were second in 1984-85 (Table 5). Small shorebird use-days per five hectares ranked as the highest among bird groups in Klopp Lake during both years and in Hauser Marsh in 1985-86 (Table 5; Figures 30, 31).

Gulls and terns decreased significantly (p<0.05) in bird use-days from 1984-85 to 1985-86 in both Klopp Lake and the Marsh Project as a whole (Table 5). They decreased by 53.4 percent over the entire Marsh Project and by 53.8 percent in Klopp Lake (Table 5; Figures 31, 39). The decrease was mostly of ring-billed gulls, western gulls and mew gulls (Tables 2, 3, Figure 28).
Figure 38. Small Shorebird Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Figure 39. Gull and Tern Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
Fourty times more gull and tern use-days per five hectares occurred in Klopp Lake than in the other units combined and most of the rest were in Hauser Marsh (Table 5; Figures 31, 39).

All 15 species of gulls and terns observed on the Marsh Project during this study were present on Klopp Lake, eight species were found in Hauser Marsh, five species in Gearheart and three in Allen Marsh (Tables 2, 3).

Gulls and terns were the third most numerous bird group in 1984-85 and sixth in 1985-86 on a Marsh Project wide basis (Tables 4, 5). In Klopp Lake, they were third most numerous in 1984-85 and fourth in 1985-86 (Table 5; Figures 30, 31).

Raptor use-days per five hectares significantly increased (p<0.05) in Allen Marsh (by 38.2 percent) between 1984-85 and 1985-86 (Table 5, Figure 40). Raptors increased in the Marsh Project as a whole by 23.2 percent (Table 5).

More than half of the raptor use-days per five hectares were recorded in Allen Marsh (Table 5, Figure 40). Klopp Lake received the second highest Raptor use in both years and Gearheart Marsh was third (Table 5, Figure 40).

Ten of the 13 species of Raptors observed on the Marsh Project were recorded on Allen Marsh, nine species in Gearheart Marsh, seven in Klopp Lake and six in Hauser Marsh (Tables 2, 3).

Raptor use-days were the lowest among bird groups for the entire Marsh Project in both years (Table 5). They were the lowest in Hauser Marsh and Klopp Lake also but ranked seventh in Gearheart and Allen Marshes in each year (Table 5).
Figure 40. Raptor Bird Use-Days per Five Hectares on High Tide Surveys on the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986 (n = 320 High Tide Surveys). SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).
DISCUSSION

Vegetation Growth Patterns

Natural succession tends to fill in wetlands gradually, eventually creating an upland, unless the wetland is disturbed periodically by natural phenomena such as drought, fire or floods. In the Marsh Project wetlands the hydrach succession patterns may follow those of bogs; with floating mats of vegetation encroaching from the shore covering the water surface and then slowly filling in the water column below the mat with detritus. At the Marsh Project vegetation was already creeping in from the edges and covering the surface with vegetative mats by September 1987 (Figures 5, 7). The high nutrient concentration of the wastewater will encourage this process. The Marsh Project wetlands were man-made and the City of Arcata will be able to manipulate the environment in several ways to maintain open water.

During this study and including the first year of wastewater use (1986-87), the vegetation in Gearheart Marsh grew rapidly reducing the open water area of the marsh by 20 percent (Table 1, Figure 5). Without periodic vegetation harvesting or other means of removing Marsh Pennywort and Common Cattail, it seems likely that the marsh units will be completely covered by these two species. The city has a plan for vegetation removal that appears to maintain open water (Hull pers. Comm.). Sago Pondweed still was present in Gearheart and Hauser Marshes in early September 1987 but was not visible from the air or shoreline by the end of that month because of lesser duckweed cover. Because sago pondweed has a high wildlife value, the possible decline of this species in the marsh units is cause for concern.

88
**Sago Pondweed**

Sago pondweed has been considered the single most important waterfowl food plant in North America (Yeo 1965, Anderson and Low 1976). In addition to its food value, sago pondweed also provides habitat for invertebrates which are important waterfowl food (Krull 1970). All parts of the plant are eaten by waterfowl from the fruits to the subterranean tubers and everything in between. Anderson and Low (1976) reported that waterfowl removed or disrupted, on the average, 40.4 percent of the peak standing crop of the foliage and 42.9 percent of the tubers.

Peak standing crop of sago pondweed may occur at different water depths in different water bodies depending on the turbidity of the water and the other vegetation present in the community (Robel 1961, Anderson 1978). Sago pondweed peak standing crop equivalent to 2500 kilograms per hectare dry weight were reported at a water depth of 60 cm by Anderson (1978). In this study, above substrate peak standing crops for all water depths combined in Gearheart Marsh were 1879.4 and 1130.8 kilograms per hectare for the years 1985 and 1986 respectively (Figures 8, 9). Although reported peak standing crop dry weight numbers varied greatly for sago pondweed and other submergent plants, they were generally lower than those reported for standing crops of emergent vegetation. Williams (1985) reported a mean standing crop biomass of common cattails of 25,800 and 13,186 kilograms per hectare dry weight from Arcata’s Marsh Pilot Project when it was receiving wastewater in 1981 and 1982 respectively. These number were many times that of biomasses reported for sago pondweed. With the lower peak standing crop produced by sago pondweed when compared to emergent vegetation and the removal of a significant portion of this biomass by waterfowl it makes sense to manage the marsh units for sago pondweed from a marsh maintenance standpoint.

Emergent macrophytes have been effective in removing BOD and NFR from wastewater (Kadlec 1978, Sloey et al. 1978, Williams 1985). Marsh treatment systems
appeared to remove nutrients, hydrocarbons, and heavy metals to varying degrees (Valiela et al. 1976, Bastian and Benforado 1988). The cost of building and operating these systems was generally much less than conventional treatment plants (deJong 1976, Sutherland 1985). The success of emergent macrophyte vegetation in polishing wastewater was attributed to the filter-like structure of the plant community which provides tremendous surface area for microbial attachment (deJong 1976, Williams 1985). The microbial organisms removed the organic materials in the wastewater while the macrophytes provided surface area for attachment (deJong 1976, Williams 1985). When using emergent marshes for wastewater treatment large amounts of biomass are produced which fill in the pond rapidly. Emergent vegetation has the advantage of year-around treatment due to the presence of substrate for microbial attachment even while the plants are dormant and decaying. It seemed likely that submergent plants, such as sago pondweed, could act as a biological filter during the growing season when the water column is full of these plants. Bastian and Benforado (1988) suggested that submergent vegetation provided extensive surface area for attached biological growth, which appeared to play an even more important role than plant uptake in water quality enhancement. McNabb (1976) reported nutrient removal capabilities of submergent plants used in a tertiary treatment system involving successive partial plant harvests during the growing season.

In the Marsh Project units, where treatment was secondary to wildlife habitat (Hull 1988), it makes sense to manage for submergent vegetation from a treatment standpoint as well as marsh maintenance and wildlife aspects. The one exception to this would be Hauser Marsh which is last in line and which sends water back for a second chlorination. In this marsh, a year-around filter of emergent vegetation would be important in removing as much organic matter as possible before the final chlorination to reduce the amount of trihalomethanes (chloroform, CHCl3 in particular) produced during chlorination. Natural and wastewaters contain organic matter that undergo attack
by chlorine to form chloroform rapidly during chlorination and this would be of concern because chloroform may be a carcinogen (Snoeyink and Jenkins 1980). If the State Water Resources Control Board ever allows the city to skip the second chlorination then this filter may not be necessary and the unit could then be managed for submergent vegetation again.

The methods employed for determining standing crop biomass were imprecise. The variance among the samples from each sampling date within the two water depth categories was so great that statistical analysis was impossible. In reviewing other studies on sago pondweed it became obvious that there was no easy solution to this problem. Major limitations of my data come from three causes: 1) the sampling technique had flaws leading to high variance (Rich et al. 1971, Brown 1984), 2) the contours of the marsh unit bottoms were uneven with abrupt changes between deep and shallow water, and 3) the spreading nature of the canopy of the plant.

All three of the above factors worked together to increase the variance of data sets. The modified Gerking sampler used during this study was difficult to operate because it was cumbersome, yet it covered too small an area used in very dense stands of sago pondweed it pushed the thick mat down to the bottom which forced some vegetation in the sample plot outwards away from the sampler. In less dense stands the sampler allowed the vegetation to remain floating at the surface when the sampler was placed in the water and then probably obtained a truer sample. Increasing the size of the area sampled and removing the trap door at the bottom of the sampler and using a hoe or rake to cut the vegetation at the mud surface probably would reduce the variation due to sampling error.

Sago pondweed sprouts and grows from the marsh bottom and as it reaches the surface it spreads out in all directions like a canopy of a tree (Yeo 1965). In the Marsh Project marsh units, where deep and shallow water were in close proximity because of borrow ditches, the spreading canopy of the pondweed rooted in shallow water could
extend into the water column above deep water. This also may have contributed to the
differences in mean standing crop biomass between deep and shallow water samples to
be less than the variance among the samples. If the goal is to determine the water depth
at which sago pondweed actually roots and grows, samples should be collected at the
begining of the growing season, before the plants reach the surface and begin to spread,
i.e. 7 May 1985 (Figure 8).

Avian Use

Total bird use-days for the Marsh Project was 1,434,633 in 1984-85 and
1,429,837 in 1985-86 with 98 waterbird species recorded for both years. Spitler (1985)
reported 75 waterbird species from the first year of flooding (1980-81). Nelson (1989)
reported 91 waterbird species and 3,968,218 waterbird use-days for the year 1987-88
on South Humboldt Bay. Tousley (1982) reported 63 waterbird species and 224,360
waterbird use-days for the Arcata oxidation pond for 1979-80. Funderburk (1979)
recorded an average annual total of 3,091,305 waterbird use-days on Lake Earl, Del
Norte County, California. Lake Earl was most heavily used in October-December and
the most abundant bird group was waterfowl, principally diving ducks (Funderburk
1979).

Using the bird use-days numbers from Nelson (1989), Tousley (1982) and
Funderburk (1979) and the area in hectares of each of their respective study areas, I
calculated bird use-days per five hectares for comparison of these studies with the Marsh
Project (Table 6). The Marsh Project was used at rates more than ten times those of
either Lake Earl or South Humboldt Bay and three times those of the Arcata oxidation
pond (Table 6). The data for the various areas were not directly comparable, because
85± percent of the use at the Marsh Project was by loafing shorebirds at high tide.
When only waterfowl use of the respective areas was considered the Marsh Project had
about 38 percent higher rates of use on an area basis than Lake Earl, 74 percent higher
Table 6. Comparison of the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California With Three North Coast Wetland Areas, Noted For Water Bird Use.

<table>
<thead>
<tr>
<th>Study Areas</th>
<th>Average Annual</th>
<th></th>
<th>Average Annual / 5ha</th>
<th></th>
<th>Authority</th>
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<tr>
<td></td>
<td>Water Bird Use Days</td>
<td>Waterfowl Use Days</td>
<td>Hectares</td>
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<td>Waterfowl Use Days</td>
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<td>1634.0</td>
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<td>4,346</td>
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<td>137,740</td>
<td>22.3</td>
<td>50304</td>
<td>30,883</td>
</tr>
<tr>
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<td>98,689</td>
<td>37.8</td>
<td>189,451</td>
<td>13,054</td>
</tr>
</tbody>
</table>
use than South Humboldt Bay and 57 percent less use than the Arcata oxidation pond (Table 6). The total number of bird use-days at the Marsh Project as a whole was less than the Lake Earl and South Humboldt Bay areas only because the total area of the Marsh Project units was much smaller.

**Waterbird Use at High and Low Tides**

Nearly all differences in bird use between tidal stages revealed higher use at high tide (Tables 2, 3). Therefore, future surveys of the avian use of the Marsh Project should concentrate data collection efforts at high tide unless management of the marsh units changes drastically.

Shorebirds primarily used the Marsh Project at high tide when they seek loafing sites. A future study might seek to determine the arrival patterns among the species as the bay becomes flooded and the departure patterns as the tide recedes.

Among the herons and egrets, snowy and great egrets both used the Marsh Project in significantly greater numbers during high tides. Yull (1972) reported that more great egrets used pasture land during high tide than during low tide. It appeared, however, that during times when the marsh units provided unusually high food supplies because of water level draw downs or fish die offs, these species used the Marsh Project in large numbers regardless of tide levels (Pers. Observ.). On the highest tides when much of the salt marsh Cord Grass was flooded, great egrets tended to feed in the salt marshes rather than loafing at the Marsh Project (pers. obsev.), but these details of egret foraging were undocumented.

**Seasonal Use**

Peak waterbird use of the Marsh Project occurred between winter and late spring. This contrasted to the results of Spitler (1985) who reported peaks of use in late spring and early fall to mid fall. Because shorebirds represented 87.9 percent of all bird use-days the overall seasonal patterns were strongly influenced by these groups (Table
The highest number of waterbird species recorded per season was during late fall and winter with 76 species observed in each season (Appendix A). The lowest number of species occurred during late spring and summer when 62 waterbird species were recorded in each season (Appendix A).

**Fish-Eating Divers.** Pied-billed grebes were the most common and consistent species of the fish-eating diver group (Appendix A). Pied-billed grebes were nearly absent during summer, but at least one pair nested on Hauser Marsh in 1986. They typically arrived in early fall and were common until late spring (Appendix A).

Tousley (1982) found pied-billed grebes on only four of 216 surveys at the Arcata oxidation pond during 1979-80. Spitler (1985) reported pied-billed grebes on 43 percent of her surveys during the first year of flooding in 1980-81 compared to 76 percent during this study (Appendix A).

Tousley (1982) reported eared grebes (*Podiceps nigricollis*) as the most common fish-eating diver species found at the Arcata oxidation pond and Nelson (1989) reported horned grebes (*P. auritus*) represented 60 percent of the total grebe use-days on South Humboldt Bay in 1987-88. At Arcata Marsh, horned and eared grebes arrived during late fall and remained through late spring during both years (Tables 2, 3). Horned grebes were slightly more numerous during late fall and winter and eared grebes were found in higher numbers during early and late spring (Tables 2, 3). Western grebes (*Aechmophorus occidentalis*) were the least common grebe at the Marsh Project and were uncommon visitors from late fall to late spring (Appendix A).

Double-crested cormorants were permanent residents at Humboldt Bay (Yocom and Harris 1975) and the nesting colony on the wharf ruins in North Humboldt Bay was the largest in California (Ayers 1975). Double-crested cormorants used the Marsh Project sporadically with peak numbers during late fall or winter (Figure 21). Spitler (1985) reported double-crested cormorants on 14 percent of her surveys. Tousley
(1982) reported this species on only four percent of her surveys at the Arcata oxidation pond. I found them present on 46 percent of the surveys at the Marsh Project (Appendix A).

Brown pelicans were observed from summer to late fall with peak numbers in mid to late fall (Tables 2, 3). Nelson (1989) reported peak numbers of brown pelicans in South Humboldt Bay from summer to mid fall in 1987-88. A single white pelican (*Pelecanus erythrorhynchos*) was observed on 23 and 24 November 1985 loafing on an island in Klopp Lake. White pelicans were listed as Casual visitors by Yocom and Harris (1975).

**Herons and Egrets.** Herons and egrets used the Marsh Project year round. Peak numbers occurred from early fall to late fall building up in summer from late spring lows (Figure 22).

Yocom and Harris (1975) listed snowy egrets as uncommon residents and breeders. Snowy egrets have expanded their numbers locally and were the most abundant heron recorded at the Marsh Project during this study, with great egrets second (Table 4; Figure 22, Appendix A). Nelson (1989) reported great egrets as the most numerous heron in South Humboldt Bay with peak numbers from late spring to early fall. Great egrets were least abundant during early and late spring at the Marsh Project (Table 4, Figure 22). These two seasons corresponded to the egg laying and incubation period reported from the breeding colony on north Humboldt Bay (Ives 1973). Spitler (1985) reported total percent frequencies of great and snowy egrets of 80 and 64 percent respectively from the Marsh Project. This compares to 80 and 87 percent frequencies for great and snowy egrets respectively in this study (Appendix A). Tousley (1982) reported great egrets on 14 percent of her surveys and snowy egrets on five percent at the Arcata oxidation pond.
Great blue herons (Ardea herodias) were a distant third in total numbers of herons recorded at the Marsh Project during this study. They were present on only 53 percent of my surveys, 43 percent of Spitler's (1985) surveys and only three percent of Tousley's (1982) surveys.

Less frequent species of herons recorded in this study included black-crowned night herons (Nycticorax nycticorax). They were fairly common during summer and early fall and uncommon to rare the rest of the year with no records during early spring (Appendix A). American bitterns (Botaurus lentiginosus) were uncommon during most of the year except summer and early fall when they were rare or absent completely (Appendix A). Green-backed herons (Butorides striatus) made an appearance each year during summer to mid fall when they were rare to uncommon (Appendix A). Cattle egrets (Bubulcus ibis) were rare from late fall to early spring with nearly all observations of this species represented by small flocks loafing on the leeward sides of islands in Gearheart Marsh during high winds. The first record for least bittern (Ixobrychus exilis) in Northwestern California occurred in Gearheart Marsh 7-17 July 1986.

Puddle Ducks. Although absolute peak numbers occurred during winter in both years, puddle duck numbers increased from summer and early fall lows during mid fall and remained high until early spring (Figure 23). Summer and early fall puddle duck numbers represented mostly nesting mallards and cinnamon teal and their young (Tables 2, 3). Blue-winged teal (Anas discors) were present in small numbers during each summer and early fall (Appendix A).

Green-winged teal arrived along with northern pintail, American wigeon (A. americana) and northern shoveler (A. clypeata) during mid fall (Figure 23, Appendix A). The only observations of Eurasian wigeon (A. penelope) and wood ducks (Aix sponsa) were during mid fall (Tables 2, 3, Appendix A).
Monroe et al. (1973) reported American wigeon as the most abundant puddle duck using Humboldt Bay with northern pintail second. Nelson (1989) found American wigeon to be the most numerous puddle duck on South Humboldt Bay and ranked American green-winged teal, northern pintail and mallards as second, third and fourth respectively. Tousley (1982) found northern shovelers to be the most abundant puddle duck with mallards, American wigeon and northern pintail a distant second, third and fourth respectively on the Arcata oxidation pond. In the first year of flooding, the Marsh Project was used most heavily by Mallards, followed by northern shovelers, cinnamon teal and northern pintails (Spitler 1985). Green-winged teal represented 38 percent of the total puddle duck use-days during this study, followed by mallards and cinnamon teal with 36 and 15 percent respectively (Table 4).

Diving Ducks. Seasonal use patterns of diving ducks was very consistent with the first fall migrants arriving in late fall, peak numbers in winter and near total departure by the end of late spring (Figure 24). Nelson (1989) reported peak numbers of diving ducks on South Humboldt Bay from early winter (late fall) to early spring.

Species composition shifted slightly between years with ruddy ducks being most numerous in 1984-85 and lesser scaup in 1985-86 (Table 4). Spitler (1985) found ruddy ducks to be the most abundant diving ducks during the first year of flooding. Nelson (1989) reported that the most numerous diving ducks seen on South Humboldt Bay were scaup, buffleheads (*Bucephala albeola*), and surf scoters (*Melanitta perspicillata*). Monroe et al. (1973) reported scoters to be the most abundant diving ducks on Humboldt Bay followed by scaup.

Of the 16 diving duck species observed on the Marsh Project during this study four were listed as rare to accidental by Yocom and Harris (1975). Hooded mergansers (*Mergus serrator*) were rare visitors during late fall and winter and oldsquaws were rarely seen in summer (Appendix A). A single female barrow's goldeneye (*Bucephala islandica*)
was observed on Gearheart Marsh on 26 November 1985 during an ornithology field trip. A single female tufted duck (*Aythya fuligula*) was discovered on 22 November 1985 among 300 scaup on Klopp Lake. This bird remained in the area through the winter. A male tufted duck in breeding plumage spent the late spring of 1986 in Klopp Lake and Hauser Marsh.

**Coots and Rails.** The Coots and rails group was predominately made up of American coots (99.9 and 99.4 percent of annual use-days) (Table 4). Soras (*Porzana carolina*) and virginia rails (*Rallus limicola*) were both present but rarely seen. These two species are secretive and were probably missed by surveys more often than they were recorded. Spitler (1985) reported no rails during the first year of flooding. American coots were generally common residents with only a few birds present each summer (Appendix A). Coots were most abundant in late fall and winter (Figure 25). Monroe et al. (1973) reported coots to be most numerous during winter and generally used freshwater marshes and sloughs surrounding Humboldt Bay.

**Large Shorebirds.** Large shorebirds were nearly absent during summer but were present in large numbers by early fall (mid July) and generally increased until their winter peak use (Figure 26).

Marbled godwit numbers were fairly stable from mid fall to early spring in both years (Table 4, Figure 26). The overall peak in winter for large shorebirds can be attributed to the definite peak numbers of american avocets and willets in that season (Table 4, Figure 26). Evans (1988) reported peak numbers of american avocets in North Humboldt Bay from November to January for the years 1982-83 and 1983-84.

Gerstenberg (1972) reported that marbled godwits arrived in late July and early August (early fall), declined in mid-September (mid fall) and increased again in October (late fall) remaining high through December. The only fall decline in marbled godwit use of the Marsh Project during this study was in late fall 1985 when godwit use-days
dropped 45 percent from the previous mid fall period (Table 4). I suspect this decline was caused more by a shift to an alternative high tide roost than migration away. In particular, a newly-constructed dike in the Arcata oxidation pond was used heavily by shorebirds during that period (pers. observ.).

The peak numbers of american avocets recorded during this study match closely with those of Evans (1988). Evans (1988) reported a peak population count of 736 on 22 January 1985. My peak counts were 725 on 17 January 1985 and 800 on 6 January 1986. This close agreement emphasised the probable accuracy of my estimation techniques which involved extrapolating numbers from counting small portions of the flocks of shorebirds packed closely together on the islands. American avocets were often the easiest species to count directly because of their striking color pattern. They are nearly the same size as marbled godwits and willets and, therefore, I often used avocets as a base reference in estimating the total number of large shorebirds present on the loafing islands. Each species presents a particular set of problems to a population estimator. Marbled godwits stood close together and the blending of their colors makes it difficult to differentiate individuals. Willets were easy to separate among godwits but their irregular spacing made it necessary to take care not to overlook them. Dowitchers basically disappeared from view among the larger shorebirds and many were undoubtedly overlooked. Black-bellied plovers typically roosted away from the larger shorebirds and therefore direct counts of the well-spaced individuals was fairly easy.

No attempt was made to differentiate between long-billed (*Limnodromus scolopaceus*) and short-billed dowitchers (*L. griseus*). The birds were too far away to use plumage characteristics and calls were not heard frequently enough to be useful. Gerstenberg (1972) reported that peak numbers of dowitchers in the Humboldt Bay region occurred during migration in both spring and fall. This agrees well with the two peaks observed during this study (Table 4, Figure 26). Spitler (1985) also reported low numbers of dowitchers in winter and peaks in fall and late spring.
Two species of large shorebirds nested on the Marsh Project, both in Allen Marsh. Killdeers (*Charadrius vociferus*) were uncommon most of the year except in late spring and summer when they were fairly common (Appendix A). Several pairs nested in Allen Marsh in 1985 and 1986. One pair of black-necked stilts arrived on 24 April 1986 (late spring) and nested successfully in Allen Marsh, only the second known nesting record for Northwestern California. Two young were seen on 8 July and three were observed on 28 July 1986. On 14 August 1986 I observed two young black-necked stilts fly 20-100 meters. Two pairs of black-necked stilts arrived in late spring 1987 and both pairs nested. Black-necked stilts were listed as Accidental on the North Coast by Yocom and Harris (1975). Spitler (1985) reported a black-necked stilt on Gearheart Marsh on 8 and 10 April 1980.

**Small Shorebirds.** As a group, small shorebird use peaked in late spring each year (Table 4, Figure 27). They were absent in summer and the first fall migrants arrived in early fall (Table 4, Figure 27). Spitler (1985) reported peak numbers of small shorebirds in early fall during the first year of flooding with a second (slightly lower) peak in late spring.

Gerstenberg (1972) reported no western sandpipers in the Humboldt Bay area during late May to Late June (summer) and very small numbers of least sandpipers and dunlins. Gerstenberg (1972) reported that the first small sandpipers to arrive during the fall migration were western and least sandpipers in early July (early fall). Western sandpipers declined during late fall or winter during this study and increased to a peak in early and late spring (Table 4, Figure 27). Gerstenberg (1972) observed a decrease in western sandpipers during winter and a sudden "avalanche" of spring migrants in late April and early May (late spring). Dunlins arrived at the Marsh Project in early October (mid fall) and maintained fairly stable numbers through the winter and spring (Table 4,
Gerstenberg (1972) reported that dunlins arrived in early October and moved north in late April.

The large peak of western sandpipers in late spring each year corresponds well with the "avalanche" of spring migrants described by Gerstenberg (1972) (Table 4, Figure 27). The peak number of western sandpipers was 18,200 on 20 April 1986.

Lesser golden plovers (*Pluvialis dominica*) were rare migrants during late fall and late spring in 1985-86 (Appendix A). A single solitary sandpiper (*Tringa solitaria*) was seen on 25 August 1986 in Allen Marsh. Solitary sandpipers were listed as casual by Yocom and Harris (1975). Two baird's sandpipers (*Calidris bairdii*) were observed 6-18 August 1985 in Hauser Marsh when it was drawn down. Pectoral sandpipers (*C. melanotos*) were uncommon to rare in mid fall and late fall both years (Appendix A). Baird's and pectoral sandpipers were listed as rare by Yocom and Harris (1975). A stilt sandpiper (*C. himantopus*) was observed on Hauser Marsh, during its drainage, on 13-15 July 1985 and another bird was seen on Allen Marsh on 8 and 11 July 1986. Yocom and Harris (1975) listed stilt sandpipers as casual. Single semipalmated sandpipers (*C. pusilla*) were observed twice; one 14-18 August 1985 in Hauser Marsh and another on the south shore line of Klopp Lake 7 August 1986. One sharp-tailed sandpiper (*C. acuminata*) was observed on 4-5 October 1985 in Hauser Marsh and 6 October 1985 in Gearheart Marsh when Hauser Marsh was flooded with water drained from Gearheart Marsh. Both semipalmarated and sharp-tailed sandpipers were listed as accidental by Yocom and Harris (1975).

**Gulls and Terns.** Gulls and terns were present all year but they were most common in spring and fall migration (Table 4, Figure 28). The three most common and regular species were ring-billed, western and glaucous-winged gulls. Spitler (1985) also found ring-billed gulls to be the most numerous and frequently seen species during the first year of flooding of the Marsh Project. Nelson (1989) reported western gulls as
the most abundant gull on South Humboldt Bay. Tousley (1982) reported California (Larus californicus) and Bonaparte's gulls (L. philadelphia) as the most abundant gulls on the Arcata oxidation pond.

The percent frequency of all gull species was higher during this study when compared to the first year of flooding (Spitler 1985) except for Bonaparte's gulls which dropped in frequency from 21 percent to eight percent. The number of species of gulls and terns observed during this study was nearly twice (15) the number recorded by Spitler (1985) (8) in the first year of flooding.

Two common terns (Sterna hirundo) were seen with Forster's terns (S. forsteri) on 16 October 1985 and one bird was present on 22 September 1984. Yocom and Harris (1975) listed common terns as uncommon on the north coast with most records during September and October. A single first year glaucous gull (L. hyperboreus) was observed on Klopp Lake on 4 and 26 January 1985. Forster's terns were uncommon visitors from mid fall to winter each year (Appendix A). A small group of Forster's Terns had apparently begun to winter in North Humboldt Bay. Forster's terns were more frequently observed on the wharf ruins in Humboldt Bay (pers. observ.). Yocom and Harris (1975) listed Forster's terns as uncommon migrants and summer visitors to the north coast with most records for the months of August, September and October and no winter records.

**Raptors.** Peak use by raptors was during late fall and winter each year with the highest species diversity occurring in winter (Table 4, Figure 29, Appendix A).

Many of the raptors species recorded during this study were rarely seen and then only during one or two seasons (Appendix A). A single prairie falcon (Falco mexicanus) was seen on 22 November 1984 on the utility tower in Allen Marsh. Yocom and Harris (1975) listed prairie falcons as casual on the north coast. Short-eared owls (Asio flammeus) were uncommon during winter and were seen in no other season.
Osprey (Pandion haliaetus) were distinctly seasonal arriving in early spring, peaking in summer and were gone by mid fall (Appendix A). Other than the three "frequent" species of raptors, peregrine falcons was the only other species recorded during every season. Monroe et al. (1973) reported only two peregrines during a three-year study on Humboldt Bay.

**Bird Use Among Marsh Units and Between Years**

Klopp Lake received over 75 percent of the bird use in both years, on an area basis because of its high shorebird use (Table 5; Figures 34, 35). Spitler (1985) also reported highest bird use in Klopp Lake because of shorebirds, gulls and diving ducks during the first year of flooding. Gearheart Marsh received the second highest use through this study because of puddle duck, american coot and diving duck use (Table 5; Figures 34, 35). Gearheart Marsh was used at the second highest rate during the first year of flooding also, when the principal birds were american coots, shorebirds and puddle ducks (Spitler 1985). The shift in species composition in Gearheart Marsh between the first year of flooding and this study was probably because of increased water depth and the development of waterfowl food plants. Spitler (1985) found significantly different rates of shorebird use at Gearheart Marsh between periods of high water and periods of low water. High water excluded shorebirds.

Hauser Marsh was third in bird use during this study and also during the first year of flooding (Spitler 1985). The major bird groups using Hauser Marsh during this study and the first year of flooding were American coots and shorebirds (Spitler 1985).

During the first year of flooding the main bird species found in Allen Marsh were American coots, great and snowy egrets (Spitler 1985). During this study puddle ducks and American coots were the principal birds found in Allen Marsh (Table 5, Figure 34).
Four bird groups were found in significantly different (p<0.05) numbers between years on a marsh-wide basis (Table 5). The fish-eating diver group occurred in significantly lower numbers in 1985-86 than in 1984-85 mostly because of reduced numbers of double-crested cormorants and "other" fish-eating divers in Klopp Lake (Table 4, Figure 21). I have no explanation for this difference.

Puddle ducks doubled in numbers on a marsh-wide basis because of a 72 percent increase in their numbers in Gearheart Marsh principally, green-winged teal and mallards (Tables 4, 5, Figure 23). In Gearheart Marsh the peak sago pondweed standing crop was higher in 1984-85 (Figures 8, 9), but in 1985-86, nearly the entire crop became available to the birds when most of the water was drained off 6-13 October, followed by a partial reflooding (Figure 10). Many waterfowl foraged on sago pondweed during the period of low water.

Large shorebirds significantly decreased (p<0.05) between 1984-85 and 1985-86 (Table 5; Figures 31, 37) mostly because of a reduction of marbled godwits and willets in Klopp Lake (Table 4, Figure 26). This difference likely resulted from the construction of an attractive new, bare dike during 1985-86 at the Arcata oxidation pond, which was readily used by shorebirds and gulls (pers. observ.).

The significant decrease in gulls and terns marsh-wide between 1984-85 and 1985-86 was mainly because of a reduction of 50+ percent in gull and tern use-days at Klopp Lake (Tables 4, 5; Figures 31, 39). This reduction probably also was related to the newly-created dike at the Arcata oxidation pond.

The increase in puddle ducks in Gearheart Marsh was accompanied by a significant decrease of diving ducks (p<0.05) (Table 5; Figures 30, 34, 35). The three most common diving ducks in Gearheart Marsh were ruddy ducks, greater scaup, and ring-necked ducks and all were considerably less numerous in 1985-86 than in 1984-85 (Tables 1, 2). This was probably a result of shallower water depths there in the winter of 1985-86 (Figure 10).
Rates of diving duck use at Klopp Lake increased by 47.7 percent (not significant \((p>0.05)\)) probably because a heavy crop of wigeon grass was produced that year (pers. observ.). The water level dropped steadily during the summer, early fall and mid fall allowing more light to reach the plants during the growing season. The water level dropped because the stop-log control structure between Hauser Marsh and Klopp Lake had been removed in July cutting off the freshwater source to the lake.

In Hauser Marsh four bird groups were found in significantly lower numbers \((p<0.05)\) and one group in significantly higher numbers in 1984-85 than 1985-86 (Table 5). Use by small shorebirds increased from early to late fall when the water was drained from Hauser Marsh exposing bare mud (Figures 10, 38). The significant decrease in heron and egret use of Hauser Marsh can be attributed to the drainage of the unit during the seasons when herons used the Marsh Project most heavily each year (Figures 22, 33).

The last three groups to show a significant decrease in use of Hauser Marsh were puddle ducks, diving ducks and coots and rails (Table 5). Puddle duck use of Hauser Marsh during 1984-85 was concentrated during early fall and mid fall, the two seasons the unit was drained in 1985-86 (Figures 10, 34). Puddle duck use of the Marsh Project as a whole was highest during winter in both years, yet little use was recorded in Hauser, apparently plant growth during the early to late fall drainage had produced little food (Figures 10, 34). Diving duck and coot and rail use of Hauser Marsh declined to nearly zero in 1985-86 (Figures 30, 35, 36). The major difference in the marsh unit between 1984-85 and 1985-86 was that, because of the drainage of the unit, no sago pondweed or other submergent food plants were present in the unit in 1985-86, thus greatly reducing potential food for the birds. All the emergent vegetation survived the drainage intact.
Management Implications

The importance of the sago pondweed food source was reflected in waterfowl and coot use patterns between years in Hauser and Gearheart Marshes (Figure 30). When good crops of sago pondweed were produced and then made available to the birds through water level manipulation, high use resulted. In the absence of food, use by birds would be minimal. Besides sago, some food may be provided by duckweed, invertebrates and marsh pennywort seeds (McAtee 1939).

Swanson (1977) reported that adult and immature surface-feeding waterfowl consumed 98 percent invertebrates by volume on waste-stabilization ponds. Nutrient-rich effluent may be expected to increase invertebrate populations, thus possibly representing food sources for waterfowl. Voigts (1976) reported maximum numbers of invertebrates where beds of submerged vegetation were interspersed with stands of emergent vegetation. Voigts (1976) also suggested that nesting marsh birds were attracted to marshes that produce the most invertebrates.

If the goal of the Marsh Project is to show "enhancement" through providing valuable wildlife habitat, then managing for a diversity of vegetation types including submergents such as Sago Pondweed would be important. To maintain submergent vegetation, emergent and floating mat vegetation must be removed periodically to ensure open water. van Vierssien and Verhoeven (1983) reported that sago pondweed did not grow in ponds with P-PO4 levels of 3.05 mg/l or higher presumably due to shading by planktonic algae. A decrease in water transparency appears to be a major factor causing the disappearance of submerged plants in wetlands (Robel 1961, Best 1982, van Vierssen and Verhoeven 1983). Although high nutrient levels exist in the Marsh Project, planktonic algae has not appeared to be a problem to date. This may be because of the short detention time of the water in the marsh units. The flow-through system
was fed by water coming to the Marsh Project directly from the chlorination-dechlorination facility where all the organic matter in the water was killed. Planktonic algae must recolonize the marsh units, grow and reproduce rapidly if any densities of algae are to develop. Shading of sago pondweed by floating plants such as duckweed, water fern (Azolla sp.) and marsh pennywort is a potential and developing problem at these units.

A monitoring schedule for the presence or absence of the submergents and the condition of the plants should be conducted. If the submergents are able to sprout, grow, flower, go to seed and then spread under the thick mats of azolla, duckweed and filamentous green algae nothing else may need to be done except manipulating water levels to allow the waterfowl access to the plants when they arrive in mid fall. If the sago pondweed is found unhealthy and does not complete its life cycle under the mats of these free floating plants then steps to control the floating plants should be taken. Such steps may include, 1) taking one unit out of the waste water flow pattern and replacing its water source with well water (hence reducing nutrient levels), or 2) using salinity provided from Jane's Creek diversion or North Humboldt Bay to hinder the floating plants growth. Sago pondweed is fairly tolerant of salinities up to 9,000 ppm (Teeter 1965, van Vierssen and Verhoeven 1983). Duckweed is tolerant of salinities up to 3000 ppm (Sculthrope 1967).

The Marsh Project system has water control structures built into the system (Figure 4) that could be used to "enhance" the value of the habitat for wildlife. Periodic draw downs to stimulate plant growth, simulate drought, make food available to waterfowl, shorebirds and herons and to assist in vegetation management should be planned. There is general agreement that stabilizing water levels is not good management, even though our society seems to feel intuitively that stability is a good thing (Weller 1978, Mitsch and Gosselink 1986). Harris and Marshall (1963) reported spectacular growth and fruiting of sago pondweed during the first year of reflooding,
following draw down, with moderate to heavy seed crops in the second year of flooding and light to moderate growth during the third and fourth years of continuous flooding.

The Marsh Project is in close proximity to several parcels of marginal agricultural lands. Hoff (1979) reported bird use of Arcata’s agricultural lands during a year-long survey. I calculated bird use-days per five hectares of the Arcata agricultural lands using the data from Hoff (1979) for comparison with the Marsh Project. The Marsh Project total waterbird use-days per five hectares was 60 times that of the agricultural lands. Waterfowl use-days per five hectares were 50 times those of the agricultural lands. The conversion of marginal agricultural land back to marshes may thus be justified to benefit wildlife and people. This would be possible if the State Water Resources Control Board (SWRCB) allows the City of Arcata to return to a single chlorination. If the water entering the Marsh Project units were considered to be “waters of the state” then piping water to these agricultural sites would be possible. The main obstacle to returning to a single chlorination is the contribution of wildlife to the total coliform levels in the marsh system. Geldreich (1966) reported contributions of fecal coliforms per 24 hours in the feces of domestic ducks to be 5.5 times that of man.

The City of Arcata has a unique opportunity to attract tourism to the city. Tourism attributed to wildlife viewing opportunities is of major economic value to some African countries (Eltringham 1984). Closer to home, efforts to attract tourism with wildlife viewing opportunities in Oregon are showing promise (Vickerman 1988). America’s interest in nonconsumptive wildlife recreation has increased to include nearly three-quarters of the U.S. population (Vickerman 1988). The Marsh Project already has received over 100,000 visitors per year including people from all over the world. The proposed Interpretive Center for the Marsh Project and wastewater-reuse system may have a profound impact on the economy of the city.

Sixty-six users of the Marsh Project were polled during Christmas vacation 1987 to see what attracted them to the site and what they would like to see in an
Interpretive Center (Toms 1988). Response to the poll indicated that the users of the Marsh Project are very protective of the marsh and open space and many of them would prefer to see more marshes built instead of an interpretive center.

It appears that the presence of the Marsh Project has developed an attitude among the local residents that "marshes are good, the more the better, and please don't do anything to degrade our marshes." In spite of the results of the small, informal poll, tourists, school children and local residents would benefit from a well planned and run Interpretive Center. The Interpretive Center could help visitors get the most from their encounters with the Arcata Marsh and Wildlife Sanctuary and enhance their experience. Allowing people to see how the Sanctuary was built by man, how wastewater treatment is involved, and the benefits gained from reusing wastewater may be enough to stimulate them to take away a new attitude towards wetlands, wildlife and wastewater. The transfer of knowledge of wetlands to the public and policy makers has been lacking (Wentz 1988). The Interpretive Center would be an important step in transferring such knowledge.

I've been a north coast resident for nearly ten years and I am unaware of any interpretive information being available about Humboldt Bay or its surrounding wetlands. Harris (1966) raised two interesting questions: 1) Where is the planning for the appropriate tourist displays to tell the story of Humboldt Bay? and 2) Is anyone planning for man's enjoyment and utilization of the wildlife resources? I guess we are still waiting while a potentially valuable resource is being ignored.

The Community of Arcata's challenge is four fold:

1) Provide a clean effluent to the bay.

2) Maintain quality wildlife habitat and recreation values.

3) Monitor the long term effects of the wastewater effluent on plant growth, wildlife, and water quality.

4) Sharing the information, experiences, and enjoyment of this unique web of land and
water multiple uses with others so they have the opportunity to duplicate the successes and avoid the failures.

Bastian and Benforado (1988) reported that efforts are underway to fund additional wetland and water quality research initiatives and to develop technical guidance for use in developing wetland wastewater treatment projects. Wetlands have inadvertently served as natural water treatment systems for centuries (Bastian and Benforado 1988). Although wastewater reuse for wildlife habitat is a generally new concept, many wetlands have been receiving wastewater effluents for years. Natural wetlands currently are receiving numerous wastewater discharges with more than 400 sewage treatment plants discharge to natural wetlands in the southeast alone, after meeting water quality standards (Bastian and Benforado 1988). Wastewater reuse for wildlife may be beneficial but a cautionary approach should be taken (Friend 1981, Brennan et al. 1985). We need to avoid serious environmental problems such as those at the Kesterson National Wildlife Refuge where extremely high levels of selenium in agricultural drainage water were received (Bastian and Benforado 1988). Friend (1981) stated:

Waste water from treated sewage provides a potential means for increasing the amount of waterfowl habitat available, especially in more arid parts of the United States. In addition, sewage outfalls are often popular waterfowl feeding areas and sewage lagoons are used as resting and loafing areas. An adequate assessment of the safety or hazards associated with use of waste water for waterfowl habitat has not yet been made. This must be done so that if disease risks are acceptable, full utilization of this water can be realized, or if risks are unacceptable, appropriate disease prevention measures can be developed.

As long as toxicity and wildlife health problems don't occur man-made wetland systems using wastewater will be beneficial regardless of habitat quality. However, using wastewater for natural wetland water sources should be avoided unless the wastewater improves or at least maintains habitat quality, or the wastewater is the only source available.
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Appendix A. Seasonal Status of Water Birds and Raptors Recorded During 320 High Tide Surveys at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986.

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Appendix A. Seasonal Status of Water Birds and Raptors Recorded During 320 High Tide Surveys at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986. (Continued)

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Appendix A. Seasonal Status of Water Birds and Raptors Recorded During 320 High Tide Surveys at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986. (Continued)

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<td>Parasitic Jaeger</td>
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### Appendix A. Seasonal Status of Water Birds and Raptors Recorded During 320 High Tide Surveys at the Arcata Marsh and Wildlife Sanctuary, Humboldt County, California, 9 May 1984 - 21 August 1986. (Continued)

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Abundant - large numbers seen on 95% of surveys or more
Common - seen in moderate to large numbers on more than 70% of surveys
Fairly Common - seen on 50 to 70% of surveys
Uncommon - seen on 10 to 50% of the surveys
Rare - seen on less than 10% of the surveys
Casual to Accidental - species not expected on a regular basis if ever again
tr - Percent frequency > 0 but < 1.
SU = Summer (9 May - 30 June), EF = Early Fall (1 July - 21 August), MF = Mid Fall (22 August - 12 October), LF = Late Fall (13 October - 3 December), WI = Winter (4 December - 24 January), ES = Early Spring (25 January - 17 March), LS = Late Spring (18 March - 8 May).