aquatic recreation. Boating activity and size of boats and motors have been increasing nationally (Clawson and Van Doren 1984, U.S. Coast Guard 1990) and in Wisconsin, where fishing activity is the most frequent activity of boaters (Penaloza, in press). Technological advances in equipment allow greater accessibility and comfort during colder weather conditions, thus extending the boating season later into the fall. Additionally, continued lakeshore development likely has increased disturbance (Liddle and Scorgie 1980) and has led to conflicts over management of aquatic macrophytes, including wild celery and sago pondweed, which are often considered undesirable by lakeshore property owners (Wis. Dep. Nat. Resour. 1989b).

Distribution of Migrational Staging Habitat

To ensure integrity between breeding and wintering sites, suitable staging habitat providing adequate food resources and refuge from disturbance must be strategically dispersed along or near traditional migration routes (North. Prairie Wildl. Res. Cent. 1982).

The loss of staging habitat and redistribution of canvasbacks threaten populations due to: (1) their susceptibility to catastrophic events (e.g., disease, oil and toxic chemical spills, and industrial accidents), (2) the potential for habitat deterioration on the last remaining sites, and (3) stress on body condition and reserves during migration (especially for females and juveniles) due to lack of food resources adequately distributed along migration routes (Trauger and Serie 1974, North. Prairie Wildl. Res. Cent. 1982, U.S. Fish and Wildl. Serv. 1984).

Adequately distributed food resources on staging habitats may also have important cross-seasonal impacts on canvasback populations. Migrating canvasbacks have relied on these staging habitats to replenish and build the fat reserves necessary for further migration (Serie and Sharp 1989). Furthermore, fat reserves during fall may affect winter survival (Haramis et al. 1986, Serie and Sharp 1989), while fat reserves during spring may affect productivity on the breeding grounds (Korschgen 1977, Ankney and MacInnes 1978, Krapu 1981).

Canvasbacks in flight from boating disturbance.

MANAGEMENT GOALS FOR WISCONSIN CANVASBACK POPULATIONS

Population Goals

ıldığı Cooperate in achieving the proposed goal for the Upper Midwest to redistribute 50% (Oetting 1985) of the 2.5 million annual use-days for staging populations of canvasbacks on Pools 7-9 of the UMR during 1979-84 (C.E. Korschgen, unpubl. data).

As Wisconsin’s contribution, accommodate 625,000 use-days in southeastern Wisconsin during fall and spring through development of additional food resources and protection from disturbance. This goal is much higher than present levels, which have averaged about 100,000 and ranged from 45,000-159,000 annual use-days for 15 sites in southeastern Wisconsin during 1986-89 (Kahl 1990; J. Dunn and G. Jolin, unpubl. data). This goal would accommodate present use and allow for redistribution of 20% of the annual use-days from Pools 7-9 of the UMR. To achieve this goal would require, for instance, attracting about 15,500 canvasbacks to southeastern Wisconsin and supporting this staging population for about 20 days during spring and 20 days during fall or 20,000 canvasbacks for about 15 days during each season. Only experience will show whether this is possible, but at the very least alternative habitats will then be available if degradation occurs on existing sites.

Canvasbacks have responded to a lesser degree to habitat improvements from undesirable fish control projects at both Beaver Dam Lake and the DNR’s Grand River Marsh Wildlife Management Area. For several years after a 1986-87 project to control undesirable fish in Beaver Dam Lake, peak fall populations increased from an average of 20 to about 200 during fall and from 125 to 2,100 during spring (Kahl, unpubl. data). The Grand River Marsh Wildlife Management Area was surveyed less consistently than Beaver Dam Lake, but few canvasbacks were noticed there from 1985-89, prior to a project to control undesirable fish. After the control project, peak populations of canvasbacks reached 375 and 1,700 during fall 1990 and spring 1991, respectively.

Location/Distribution of Staging Sites

Develop a minimum of 3 staging sites to accommodate the goal level of use-days in southeastern Wisconsin. Multiple sites will likely disperse flocks and thereby reduce the risk of disease, reduce the potential of a catastrophic event decimating a large segment of the population, and reduce the impact of habitat degradation and excessive disturbance on any one site (U.S. Fish and Wildl. Serv. 1984, Korschgen et al. 1985). Dispersal will increase viewing and hunting opportunities and quality.

Strategically locate the sites along or near present migration routes. Specific selection of sites should reflect historic and present use by canvasbacks.
Food Resources

Develop and maintain sufficient areas of moderately dense to dense food resources to support use-day goals in southeastern Wisconsin: 720 ha of wildcelery, 540 ha of sago pondweed, or 5,440 ha of macrobenthos (Table 1). These area goals for food resources include an expansion factor of 20%, to account for the inability of cannavabs to fully and efficiently utilize all areas of food resources and to account for variability within these areas, especially the less productive outer margins. The large area for mollusks in part reflects the difficulty of delineating large homogeneous “beds” of molluscs for quantifying densities and biomass, as compared with beds of wildcelery and sago pondweed. Evidence also suggests that macrobenthos may provide a less efficient nutrient pathway for acquiring the necessary energy reserves for migrating and wintering than winter buds and tubers (Perry et al. 1986, Lovvorn 1987, Takekawa 1987). Canavasks may have to consume approximately 3 times more fingernail clams by wet weight than wildcelery or sago pondweed tubers to obtain the same amount of energy (Table 1). Furthermore, a winter bud may contain about 14 times the usable energy as that of a fingernail clam.

For each site, distribute the food resources in 2-3 relatively dense beds to increase foraging efficiency, to provide alternative feeding areas, and to enhance refuge protection.

Refuge From Disturbance

Protect migrating cannavenbs from disturbance through the following management options: establishment of inviolate refuges, waterfowl protection areas that prohibit disturbance, no-wake or nonmotorized boating zones and other boating restrictions (through spatial or temporal lake-use zoning); restrictions on fishing and/or hunting; and voluntary compliance refuges coupled with strong information and education campaigns (Kahl, in press b). The best management options for each site will be determined by size.

Table 1. Energy availability, rate of consumption, and carrying capacity of wildcelery, sago pondweed, and fingernail clams for staging and migrating cannavenbs.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Wildcelery</th>
<th>Sago Pondweed</th>
<th>Fingernail Clams</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>With Shell</td>
</tr>
<tr>
<td>Energy content (kcal/g)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry weight</td>
<td>3.92b,c</td>
<td>3.92d,e</td>
<td>1.51f</td>
</tr>
<tr>
<td>Wet weight</td>
<td>1.00b,c</td>
<td>1.00d,e</td>
<td>0.28f</td>
</tr>
<tr>
<td>Apparent digestibility (%)</td>
<td>80c</td>
<td>80d,e</td>
<td>85b</td>
</tr>
<tr>
<td>Daily energy intake (kcal/individual)</td>
<td>549b</td>
<td>540b</td>
<td>540b</td>
</tr>
<tr>
<td>Daily consumption (g/individual)</td>
<td>172</td>
<td>172</td>
<td>421</td>
</tr>
<tr>
<td>Dry weight</td>
<td>675</td>
<td>675</td>
<td>2,269</td>
</tr>
<tr>
<td>Wet weight</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Standing biomass</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Dry weight (g/m²)</td>
<td>35.6cd</td>
<td>50.0d</td>
<td>23.3a</td>
</tr>
<tr>
<td>Wet weight (g/m²)</td>
<td>139.1abc</td>
<td>—</td>
<td>125.3c</td>
</tr>
<tr>
<td>No. of food items (no./m²)</td>
<td>186bc</td>
<td>—</td>
<td>18,000kb</td>
</tr>
<tr>
<td>Annual exploitation rate (%)</td>
<td>50b</td>
<td>48d</td>
<td>25km</td>
</tr>
<tr>
<td>Carrying capacity (use-days/ha)</td>
<td>1,035</td>
<td>1,395</td>
<td>138</td>
</tr>
</tbody>
</table>

a Donnermeyer 1982; from Pool 9 of the Upper Mississippi River, Wis.
b Korschgen et al. 1988; Korschgen, pers. comm.; from Pool 7 of the Upper Mississippi River, Wis.
c Takekawa 1987; from Pool 7 of the Upper Mississippi River, Wis.
d Anderson and Low 1976; from Delta Marsh, Manitoba.
e Assumed similar to wildcelery with similar nutrient composition.
f Thompson and Sparks 1978; from Pool 19 of the Upper Mississippi River, Ill. and Iowa.
g Brey et al. 1988; from a review of several studies on several species of bivalves and gastropods.
h Lovvorn 1987; from a review of several studies.

i Calculated from data in Takekawa 1987; 19.4% of day feeding (16,762 sec), diving time of 14.8 sec, total dives/day of 1,133, foraging efficiency of 0.86 winter buds/dive, daily consumption of 974 buds/day, and apparent metabolizable energy of 0.554 kcal/winter bud.

j Korschgen and Green 1988; from Pool 7 of the Upper Mississippi River, Wis.
k Thompson 1973; from Pool 19 of the Upper Mississippi River, Ill. and Iowa.
1 Sterling 1970; from Bear River Refuge, Utah.
m Gale 1969; from Pool 19 of the Upper Mississippi River, Ill. and Iowa.
and configuration of open water at the site, distribution of food resources, hunter behavior, fall and spring fishing pressure, recreational boating patterns, and shoreline development patterns. Canvassbacks and other diving ducks will tolerate some disturbance if the area is large enough for birds to temporarily escape to undisturbed waters for loafing and roosting and if food is accessible during part of each day (possibly at least 40%, i.e., 9-10 hours: Day 1984, Takekawa 1987) (Thornburg 1973; Kahl, in press b). Large oval or round water bodies with prohibited open-water hunting may provide adequate protection. However, fishing and recreational boating activity on many sites can result in excessive disturbance in both fall and spring. Frequent boating disturbance from hunters and anglers has been documented for several staging sites (Korschgen et al. 1985, Kahl, in press b). See Appendix A for more information on these management strategies.

If inviolate refuges or waterfowl protection areas are established, configure them to encompass at least 250 ha in a square or round shape with a buffer zone of at least 0.8-1.0 km on all sides (Korschgen et al. 1985; Kahl, in press b). Actual size and configuration will depend on the degree of inviolateness. Including a feeding site in the refuge may be essential if disturbance restricts access to food resources elsewhere. Refuges should be located to restrict the least number of users. Establishing inviolate refuges is the most effective option, but waterfowl protection areas coupled with strict enforcement can also be very effective. No-entry refuges are presently illegal on navigable waters in Wisconsin, since the Northwest Treaty Ordinance of 1787 and the federal legislation creating the State of Wisconsin and its constitution guarantee the right of free navigation on public, navigable waters.

For no-wake or nonmotorized zones, configure them to encompass larger areas than refuges. This type of zoning will only be effective at some sites.

Plan and implement an information and education campaign to increase public acceptance of the need for user restrictions, regardless of the management alternative selected.

A dense bed of wild celery such as this one can produce winter buds to sustain about 1,000 canvassback use-days per hectare (photo by the author).

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**RESEARCH STRATEGY**

**Background**

As assembly of baseline information for this research plan progressed, it became obvious that there were numerous information needs critical to the refinement and implementation of a management plan for achieving the goals just outlined. There was a lack of adequate data on canvassback staging populations, the availability of food resources for most staging habitats in Wisconsin, and the energy requirements of migrating canvassbacks. Rather than quantitative data, subjective estimates of canvassback use and food resources, based on experience of field managers, were the only available information for most sites. Additionally, there was a scarcity of recent data on water quality and other limiting or detracting factors for most sites. The literature review further revealed little quantitative study of the mechanisms and interrelationships of the major factors that are suggested as causative agents of habitat degradation. There also was a lack of information on the ecosystem processes and overall benefits to fish, wildlife, and water resources associated with management of these degradation factors.

The following plan outlines the research strategy for gathering baseline data prior to development of management plans. Management considerations and a general approach for accomplishing the goals set forth in this report are then outlined in Appendix A. Information in this appendix on the factors contributing to habitat degradation indicates the complexity and interrelatedness of these factors and justifies the recommended approach of comprehensive ecosystem management for large, shallow lakes.

**Strategy**

This research strategy embodies a step-by-step approach for obtaining the baseline information necessary to formulate restoration plans for canvassback staging habitat and populations. First, the present status of canvassback staging populations and staging habitat in southeastern Wisconsin should be determined. Next, factors limiting abundance of aquatic macrophytes and macrobenthos on the study sites should be identified; only then can appropriate restoration techniques be recommended and evaluated. The experimental design should incorporate evaluation for some restoration techniques (e.g., transplanting of submerged macrophytes, exclusion of undesirable fish and waves from experimental plots, breakwaters). Other techniques should