Harvest & Transport Best Management Practices

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Overview

• Purpose of transport
  – Fisheries enhancement, long-term survival.
  – Live haul to fish market; short-term survival.
  – Direct to slaughter facility.

• Walleye transportation study: Review physiological processes.

• Best Management Practices

• Transport density survey
Walleye transport study

- Transport walleye fingerlings (~200 mm)
  - Sport Fisheries enhancement stockings.
  - Duration of about 5-6 hrs.

- Three-year study compared:
  - Year 1: Vented and unvented transportation.
  - Year 2: Vented and Ram vented transportation.
  - Year 3: Buffered water in a Ram vented tank.

- Physiological processes during:
  - Harvest and loading
  - Transport
  - Post-transport
Pre-harvest preparation

- Suspend feeding
  - Small fingerlings 12-24 h
  - Large fingerlings 24-48 h

- Physiological Basis
  - Clears gut and reduces production of solid wastes.
  - Reduces the post-feeding increase in $O_2$ consumption and $NH_3$ excretion.
Harvest
Loading fish
Harvest and loading stress

- Efforts to capture increases fish’s muscular activity, production of lactic acid (acidosis), and an oxygen debt.
- Physiological Measures of Stress in Plasma:
  - Cortisol, Glucose, Chlorides
- Stress effects
  - Cortisol increase causes branchiodilation to increase gas exchange, but water uptake is increased.
  - Chlorides decrease (loss through diuresis).
- Consequence: Substantial increase in inflow of water through the gills, causing life-threatening loss of the electrolytes (Na and Cl).
Year 1: Harvest and loading stress

<table>
<thead>
<tr>
<th></th>
<th>Cortisol</th>
<th></th>
<th>Chlorides</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trip 1</td>
<td>Trip 2</td>
<td>Trip 3</td>
</tr>
<tr>
<td>Pre-loading raceway</td>
<td>20.2</td>
<td>0.6</td>
<td>41.1</td>
</tr>
<tr>
<td>Post-loading</td>
<td>71.7</td>
<td>54.4</td>
<td>128.9</td>
</tr>
<tr>
<td>End of trip</td>
<td>82.9</td>
<td>17.9</td>
<td>71.5</td>
</tr>
<tr>
<td>Day after</td>
<td>34.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Trip 1, 2 tanks were unvented, Trip 3 was vented.

Evidence for stress: Cortisol values triple after loading, decline.

Trips 1 and 2: 0.25% NaCl in tank water, but blood chlorides decrease after loading and do not recover.

Trip 3 had 0.5% NaCl in tank water and blood Cl remained steady.
Fish hauling tanks may have great features

Fiberglass, aluminum, stainless steel with dump gates, oxygen flow meters, openings for mechanical aerators, and latching lids with tight seals.

Source: Unknown

Compressed oxygen tanks or liquid oxygen (LOX)

Fresh-flo Corp, Sheboygan, WI

And more…
Oxygenation and monitoring

- OxyGuard Pacific 8 Monitoring System.
  - DO probes in each tank
  - 8 channel splitter
  - Display in cab
    » 1-4 conductor cable from main unit to the channel probe Unit.
    » Simplified connectivity.

But...
Many transport tanks

- Are not equipped to monitor oxygen
- Nor are they equipped to remove CO₂.
- Most tanks have no opening or only a small opening in the lid for air exchange.
**CO₂ in tank with small opening in lid**

- Aerator moves CO₂ from water to air space, but soon high pCO₂ in air reduces exchange of CO₂ from water.
- Use of compressed or liquid O₂ is required for high densities of fish. But without monitoring and mechanical aeration, supersaturation and hyperoxia develops.
- Oxygen supersaturation reduces gill ventilation rate, thus reduces elimination of CO₂ from the blood.
$\text{CO}_2$ in tank with small opening in lid
Year 1: Comparison of CO$_2$ in tanks with and w/o a vent*

<table>
<thead>
<tr>
<th></th>
<th>Without vent</th>
<th>With vent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO$_2$</td>
<td>O$_2$</td>
</tr>
<tr>
<td>Pre-load</td>
<td>46.1</td>
<td>9.5</td>
</tr>
<tr>
<td>Loaded</td>
<td>58.7</td>
<td>9.4</td>
</tr>
<tr>
<td>End of trip</td>
<td>64.7</td>
<td>13.4</td>
</tr>
</tbody>
</table>

*Ventilation was a 6.3 cm hole, which was covered in unvented tanks.

**Small vent in lid did not improve water quality compared to no vent.**
“Failure to adequately remove dissolved CO$_2$ results first in hyper-capnia and acidosis, then respiratory stress from the Bohr and Root effects, tissue hypoxia, and eventually CO$_2$ narcosis and death (Wedemeyer 1996)”

CO$_2$ induces characteristics of anesthesia
- Loss of equilibrium
- Non-responsive to audio/visual, tactile stimuli
- Ventilation rate slow
“Covered tanks require forced ventilation of the headspace to continuously remove CO₂ stripped from the water by the aeration system. Air scoops or vents mounted on the top surface can be used to provide the required airflow by ram ventilation while the hauling vehicle is in motion (Wedemeyer 1996:page 127).”
Ram Ventilation Design

Air intake

Exhaust

Aerator motor

2” PVC Male adapter

2” PVC Female adapter

2” PVC “Sweep 90”
Year 2: CO$_2$ and pH in tanks with RV or small lid vent (control)
$\text{O}_2$ and temperature in tanks with RV or small lid vent (control)
Comparison of blood parameters in tanks with and w/o RV

<table>
<thead>
<tr>
<th></th>
<th>pCO₂</th>
<th></th>
<th>pO₂</th>
<th></th>
<th>HCO₃</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W/O</td>
<td>RV</td>
<td>W/O</td>
<td>RV</td>
<td>W/O</td>
<td>RV</td>
</tr>
<tr>
<td>Pre-load</td>
<td>11.8</td>
<td>10.4</td>
<td>7.4</td>
<td>6.1</td>
<td>10.7</td>
<td>9.8</td>
</tr>
<tr>
<td>Post-load (tank lids open)</td>
<td>11.2</td>
<td>10.1</td>
<td>8.0</td>
<td>10.5</td>
<td>9.9</td>
<td>11.9</td>
</tr>
<tr>
<td>Post-haul</td>
<td>19.8</td>
<td>9.0</td>
<td>6.7</td>
<td>7.5</td>
<td>21.5</td>
<td>14.6</td>
</tr>
</tbody>
</table>

High CO₂ shifting acid–base balance, increasing concentration of blood bicarbonate in unvented tanks

\[
\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}^+ + \text{HCO}_3^-
\]
drops pH

Bohr effect of CO₂ reduces O₂ carrying capacity of Hb.
0.05% sodium bicarbonate buffer. Note: pH values of buffered water were more similar to lake water than the unbuffered water.
Year 3: Buffer use, blood chemistry comparison

Post transport observation in lake net pens:
- Post stock observations:
  - Cortisol reached a maximum of 175 to 204 ng/mL.
  - Blood CO$_2$ and Chloride at minimums.
- 24-h post haul recovery:
  - Cortisol returned to pre-loading levels.
- 72-h post haul recovery:
  - Chloride returned to pre-load levels.
- In one trip buffer reduced recovery time to return to pre-loading blood pH.
Summary of Effects on Blood Electrolytes

Stress of harvest and loading
— increase Cortisol.
— increases muscular activity and lactic production, potential for acidosis.
— causes increase in water uptake resulting in increased excretion (diuresis) and loss of chlorides.
Summary of Respiratory Effects

• In fish, oxygen controls ventilation.
  – Low oxygen increases ventilation, but
  – High oxygen causes a marked reduction in gill ventilation, thereby reducing elimination of CO$_2$ from the blood.

• High levels of CO$_2$
  – CO$_2$ lowers blood pH but homeostatic response is to compensate by increased blood levels of bicarbonate.
  – CO$_2$ produces the Bohr effect, reducing the ability of Hb to transport O$_2$ from the gills to the rest of the body.
BMPs for Harvest and Loading*

- Harvest only healthy fish.
- Discontinue feeding 24-48 h before harvest.
- Develop low-stress harvest procedures (gentle, softmesh netting to avoid physical injury, avoid crushing and loss of scales).
  - Evaluate light sedation to reduce stress.
- Need for the tanks to be well-oxygenated prior to loading because of the high demand.
- Tank covers must be open to vent CO$_2$ while stationary.
- Buffer and salt mixed in tank water before adding fish.

* See Table 1 chapter by Carmichael 2001 in Wedemeyer 2001 (FHM 2nd edition).
BMPs for Transport Tanks

- LOX tanks with micropore diffusers.
- Monitoring and control of oxygen concentration.
- Mechanical aeration
- Ram ventilation
- Salt (0.5% w/w)
- The need for buffering is based on alkalinity of water –
  - Sodium bicarbonate for water of low alkalinity (Wedemeyer 1996).
  - a tris buffer, tris[hydroxymethyl aminomethane] (5-10 mg/L) is recommended for general use (Piper et al. 1982)
## Transport density survey

78% of state agencies reported: AR, IA, KS, MI, MO, NE, SD, TN, TX, VT, WI.

<table>
<thead>
<tr>
<th>States</th>
<th>Temp (F)</th>
<th>Survey Lb/gal</th>
<th>Piper et al. Lb/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walleye</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8”</td>
<td>IA, WI</td>
<td>60-70</td>
<td>0.5-0.85</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>45-55</td>
<td>1.0</td>
</tr>
<tr>
<td>4”</td>
<td>IA, MO</td>
<td>70-85</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>45-55</td>
<td>1.0</td>
</tr>
<tr>
<td>2”</td>
<td>7 states</td>
<td>65-77</td>
<td>0.25-0.5</td>
</tr>
<tr>
<td></td>
<td>WI, MI</td>
<td>59-77</td>
<td>0.5-1.1</td>
</tr>
</tbody>
</table>

Edwards KCl/Formalin treatment: IA, KS, MO.
0.075% KCl + 25 ppm formalin
NaCl is commonly used at 0.25% or 0.5% but rarely at 0, 0.75, 1%.
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<th>Survey Lb/gal</th>
<th>Piper et al. Lb/gal</th>
</tr>
</thead>
<tbody>
<tr>
<td>8” Channel Catfish</td>
<td>8 states</td>
<td>60-80</td>
<td>0.5-2.8</td>
</tr>
<tr>
<td>TX</td>
<td>72-79</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>70-80</td>
<td>2.0-1.2</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>60-70</td>
<td>2.6-2.0</td>
<td></td>
</tr>
<tr>
<td>KS</td>
<td>&lt;60</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>2” Morone cross</td>
<td>6 states</td>
<td>65-86</td>
<td>0.25-0.60</td>
</tr>
<tr>
<td>4” Morone cross</td>
<td>3 states</td>
<td>55-85</td>
<td>0.5 – 1.0</td>
</tr>
<tr>
<td>8-10” Trout</td>
<td>8 states</td>
<td>41-60</td>
<td>1-2.0</td>
</tr>
</tbody>
</table>
Research Recommendations

- Determine walleye sensitivity to CO$_2$: 50 ppm catfish, 20-30 ppm salmonids.
- Determine maximum loading densities for transport:
  - Fish size
  - Temperature
  - Duration of travel
  - Evaluate BMPs for hauling tanks.
- Evaluated long term consequence of light sedation and stress on post stocking survival.