SOUTHERN REGIONAL AQUACULTURE CENTER

SRAC Publication No. 392
August 2023
Revision

Transportation of Warmwater Fish:

Procedures, Loading Rates, and Tips by Species

Anita M. Kelly and Luke A. Roy*

Aquaculture facilities often need to transport fish. The destinations can be from the hatchery to a pond, from a farm to another farm, or from a farm to the marketplace. Fish can be transported in buckets, hauling boxes, or small or large hauling trucks (Fig.1; see SRAC Publication 300, *Transportation of Warmwater Fish: Equipment and Guidelines*), or they can be shipped in boxes (see SRAC Publication 3903, *Shipping Fish in Boxes*).

The primary goal of transporting fish is to keep them alive and healthy. However, fish handling, density, temperature, water quality, and the type of aeration used can all cause stress in fish. Reducing stress can increase survival and decrease the chance of disease outbreaks following transport.

Although transporting fish is common, little information exists regarding species-specific transportation. This publication provides:

- General guidelines on transportation methods that can help reduce stress in fish
- Factors involved in the calculation of loading rates
- Other methods to reduce stress

The information is based on experience, research, and communication with live haulers. Many unpredictable things, such as truck or equipment failure, can happen when transporting fish. Use this fact sheet as a guideline; it is prudent to be conservative in the calculations.

Figure 1. Large vehicle used to transport fish.

Fish-Loading Guidelines for Hauling Tanks

Research is lacking on the loading densities of several fish species, and hauling density is very species-specific. Loading and hauling densities also depend on many other factors, such as species size and age, haul duration, water temperature, and oxygen system or type. However, general guidelines have been developed to assist in the calculation of densities suitable for many but not all species. Use the following calculations as a guide. Note that these densities may need to be adjusted, depending on the species, hauling distance, and temperature.

Knowing the number or weight of fish that can be loaded into each hauling compartment on a truck or in a bag is critical to successful hauling and transport. First, determine the size of the hauling tank by measuring its inside length, width, and height. To calculate the volume of a hauling tank, measurements must be in the same units. Volume is calculated as follows:

$$Volume = length \times width \times height$$

*Alabama Fish Farming Center, Auburn University

Once the volume is determined, use the units in Table 1 to convert to gallons.

Table 1. Conversion factors used to convert various measurements to gallons of water.

Unit of measurement	Conversion factor to gallons
1 cubic inch (cm^3)	0.00433 (0.000264)
1 cubic foot (m^3)	7.48 (264.2)
1 cubic yard (m^3)	201.97 (264.2)

For example, if the tank is measured in inches, multiply the length, width, and height to obtain the size of the tank in cubic inches, and multiply by 0.00433 (0.000264 for cm^3) to determine the number of gallons the tank will hold.

Although the hauling tank volume has now been determined, this is not the amount of water to use when hauling fish. When fish are added to the hauling tank, water is displaced. Therefore, gallons of water should be determined before the fish are loaded. The change in water volume (water displaced) after fish are added can be measured to determine the loading rate, as expressed in pounds per gallon:

$$\text{Loading density (lb per gallon)} = \frac{\text{Pounds of fish}}{\text{Tank capacity (gallons)} - \text{Water displaced by fish (gallons)}}$$

Table 2 provides the amount of water displaced by a known weight of fish. The water displacement factor is important for determining the capacity of a hauling unit or compartment based on the anticipated fish load in pounds.

For example: From Table 2, 12 gallons (45.4 L) of water are displaced per 100 pounds (45.4 kg) of fish weight. To calculate the size of the hauling tank to transport 1,000 pounds (454 kg) of fish weighing 250 pounds/1,000 (113 kg/1000 fish) at 5 pounds (2.3 kg) per gallon (3.785 L), your tank needs at least 200 gallons (757 L) of water based on loading rate and 120 gallons (454 L) for displacement, or 320 gallons total (1,211 L).

Loading densities will also vary, based on the water temperature and the hauling distance. Charts have been developed for some species to indicate the loading densities of specific fish species based on the hauling distance. These charts, when available, are included under the individual species listed in this fact sheet.

Table 2. Approximate number of gallons of water displaced by a known weight of fish pounds (kg).

Weight of fish pounds (kg)	Gallons (L) of water displaced
100 (45)	12 (45)
200 (91)	24 (91)
300 (136)	36 (136)
400 (181)	48 (182)
500 (227)	60 (227)
600 (272)	75 (284)
700 (318)	84 (318)
800 (363)	96 (364)
900 (408)	108 (409)
1,000 (454)	120 (454)
1,100 (499)	132 (500)
1,200 (544)	144 (545)
1,300 (590)	156 (591)
1,400 (635)	168 (636)
1,500 (680)	180 (681)
1,600 (726)	192 (727)
1,700 (771)	204 (772)
1,800 (816)	216 (818)
1,900 (862)	228 (863)
2,000 (907)	240 (908)
2,100 (953)	252 (954)
2,200 (998)	264 (999)
2,300 (1,043)	276 (1,045)
2,400 (1,089)	288 (1,090)
2,500 (1,134)	300 (1,136)
2,600 (1,179)	312 (1,181)
2,700 (1,225)	324 (1,226)
2,800 (1,270)	336 (1,272)
2,900 (1,315)	348 (1,317)
3,000 (1,361)	360 (1,363)
3,100 (1,406)	372 (1,408)
3,200 (1,451)	384 (1,454)
3,300 (1,497)	396 (1,499)
3,400 (1,542)	408 (1,544)
3,500 (1,588)	420 (1,590)
3,600 (1,633)	432 (1,635)
3,700 (1,678)	444 (1,681)
3,800 (1,724)	456 (1,726)
3,900 (1,769)	468 (1,772)
4,000 (1,814)	480 (1,817)

Loading Rates for Shipping Fish in Boxes

For smaller fish, large plastic bags (18 × 32 inches, 46 × 81 cm) are generally used for fish transport. Flat-bottom bags are preferred to avoid corner collapse, which can suffocate large numbers of fry that become trapped when pockets form. To help minimize punctures, bag thickness should be 4 mil. Bags are usually doubled to ensure that they remain airtight if one should leak.

Follow these steps to use plastic bags for shipping fish in boxes:

1. Fill the plastic bags with water, fish, and oxygen. The number of fish placed in each bag is determined by estimated travel time and fish species, size, and weight. Usually, each bag is filled so that ¼ of the volume is water (2 gallons [7.6 L] is typical), and ¾ will be oxygen.
2. Remove the remaining air by hand, compressing or squeezing it from the bag.
3. Refill the bag with pure oxygen gas through a flexible tube attached to a small, compressed-gas cylinder.
4. Twist the neck of the bag and then seal it tightly with one or more large rubber bands or livestock castrator bands.

Table 3 provides general guidelines for shipping a variety of fish species for various transport times.

Table 3. Pounds (kg) per gallon of eggs, fry, and fingerlings that can be transported between 1 and 48 hours at 65°F (18°C).

Fish size	Travel time (hours)			
	1	12	24	48
Eggs	0.5–1.5 (0.2–0.7)	0.5–1.2 (0.2–0.5)	0.5–1.0 (0.2–0.5)	0.2–0.5 (0.1–0.2)
Yolk-sac fry	1.0–3.0 (0.5–1.4)	0.7–2.5 (0.3–1.1)	0.4–1.2 (0.2–0.5)	0.2–1.6 (0.1–0.7)
Swim-up fry	0.5–2.0 (0.2–0.9)	0.4–1.6 (0.2–0.7)	0.4–1.2 (0.2–0.5)	0.2–0.6 (0.1–0.3)
1–2 inch (2.5–5.1 cm) fingerlings	1.0–3.7 (0.5–1.7)	0.9–3.2 (0.4–1.5)	0.7–2.7 (0.3–1.2)	0.3–1.3 (0.1–0.6)

Stress in Fish

Stress in fish often causes an increased metabolic rate (increased energy usage) and suppression of the immune system. An increase in metabolic rate depletes energy reserves; once depleted, the fish can no longer maintain the balance of salts within the blood, which can result in the buildup of ammonia in the bloodstream and toxic metabolites, such as lactic acid, in the muscles. As a result, the animal can die from a combination of salt imbalance and the buildup of toxic wastes. In addition, suppressed immune systems allow pathogens that fish typically resist to initiate the disease response, resulting in mortalities several days to weeks after the fish were delivered. For more information on how stress can contribute to fish disease, see SRAC Publication 474, *The Role of Stress in Fish Disease*.

Reducing stress during harvesting is essential to limiting the stress response while transporting fish. For methods to reduce stress while harvesting, see SRAC publication 394, *Harvesting Warmwater Fish*.

Research has shown that the addition of certain chemicals can improve transportation results. Any chemical used should produce an economical and proven benefit. If food fish are transported, only chemicals and drugs approved by the U.S. Food and Drug Administration (FDA) can be used. Tropical fish, ornamen-tals, and baitfish are not exempt from this restriction.

Salt

Osmoregulation is a continuous process in fish that works by maintaining the balance of salts inside their blood with the salts in the surrounding water. In freshwater fish, the salt concentration inside their bodies is higher than that of the surrounding water. As a result, freshwater fish tend to overhydrate when transported because of the influx of water across the gills and into the bloodstream. To reduce the amount of water in the bloodstream, fish use specialized cells to pump water out across the gills. The reverse is true for marine fish; the salt concentration in the water is higher than in the fish's body, so they lose water from their blood to the surrounding water. Osmoregulation is an energy-consuming process in fish, and when it is disturbed, they become stressed.

Reducing the difference between the salt concentrations inside the fish's body and the surrounding water can reduce the energy used in osmoregulation and reduce stress. For example, adding salt to shipping water for freshwater fish and reducing salt in the water of saltwater fish reduces the energy used in osmoregulation and, consequently, stress in the fish.

The most widely used drug to help reduce haul-ing stress in freshwater fish is salt (sodium chloride) without iodine and without yellow prussiate of soda (an anti-caking agent), which, unfortunately, can both be toxic to fish. Although salt is not approved for use in food fish, it is classified as a Low Regulatory Priority by the FDA.

In general, fish blood consists of a 0.9 percent (9000 ppt; 9 g/L) solution, primarily sodium and chloride salts. Therefore, adding salt to the transport water reduces the osmotic difference between the water and fish blood, lessening the effects caused by this osmotic imbalance. Several haulers use salt concentrations of 1.5 to 3 ppt to haul freshwater fish for stocking, especially when the duration of transport is 4 hours or more. Exposing freshwater fish to reduce salt concentrations stabilizes osmoregulation and increases external mucous production, which helps prevent diseases from infecting fish. The amount of salt to add to the hauling tank is provided in Table 3. Salt is added to the water before the fish are loaded.

For saltwater fish, the salinity of the water should be reduced. Most hauling waters are reduced approximately 3 to 5 ppt below the salinity of the water from which the fish were harvested. While this concentration is still higher than the salinity of fish blood, reducing the salinity of the water reduces the demand and energy needed for osmoregulation.

Anesthetics

Some species are very excitable and sensitive to handling and hauling stress. Anesthetics are useful for sedating such fish and for reducing their metabolic activity. This means less oxygen consumption and less carbon dioxide and ammonia buildup in the hauling tank water. Also, energy is conserved, enabling the fish to easier maintain ion balance. Fish can be over-anesthetized and die. Broodfish and species such as largemouth bass and hybrid striped bass respond well to anesthetics.

A popular anesthetic is MS-222. It is FDA-approved for use on food fish, but a 21-day withdrawal period is required before fish are consumed. This means that fish, such as catfish, transported to the processing plant cannot be sedated with MS-222. The recommended level of sedation during transport should permit the fish to be caught easily by hand but not cause total loss of activity or equilibrium. MS-222 is used at concentrations of 15 to 66 mg/L (ppm) for 6 to 48 hours to sedate fish during transport.

Another anesthetic that can be used on ornamental species **only** is Aquacalm® (metomidate hydrochloride). Although it is not approved by the FDA, it is legally marketed as an FDA Indexed Nonapproved New Animal Drug. It is added to the water at 0.1 to 1 mg/L (ppm) to sedate fish during transportation.

Water-Quality Considerations

Rapid changes in pH, hardness, alkalinity, temperature, salinity, and other variables may cause stress or even death in fish. However, there are ways to mitigate these effects by checking the quality of holding water, transport water, and receiving water before stocking fish. Below are some critical water-quality parameters to reduce stress and make sure that the fish arrive healthy.

Alkalinity and Hardness

Chronic fish losses or weak-fish problems are often associated with handling and transporting fish in very soft water (less than 10 ppm hardness). Hardness and alkalinity concentrations from 50 to 100 ppm are preferable. Sodium bicarbonate and calcium chloride will increase alkalinity and hardness, respectively. They are safe to use and have no restrictions. Add about 2 ounces (57 g) of sodium bicarbonate per 100 gallons (379 L) of water to increase the alkalinity by 10 ppm. Add about 1 ounce (28 g) of calcium chloride per 100 gallons (379 L) to increase the hardness by 50 ppm (Table 4).

Table 4. Types, concentrations, and quantities of food-grade salts and antifoaming agents used in live fish transport water.

Chemical name	Common name	Concentration in oz (ppt or ppm)	Teaspoons per gallon (g)	Cups per 100 gallons (g)	Pounds (kg) per 100 gallons
Sodium chloride	Mixing salt or table salt	1.1 oz /gallon (8 ppt)	4¾ (31)	9¾ (3,042)	6.4 (2.9)
Calcium sulfate	Agricultural gypsum	16.75–33.5 oz /1000 gallons (125–250 ppm) [as $CaCO_3$]	¼–4/10 (0.35–0.56)	½–8/10 (34–40.2)	0.18-0.36 (0.08–0.16)
Sodium bicarbonate	Baking soda	13.4–26.8 oz /1000 gallons (100–200 ppm) [as $CaCO_3$]	⅛–¼ (0.55–1.1)	¼–½ (53.0–106.0)	0.14–0.28 (0.06–0.13)

*Amounts listed assume that the water does not contain any of the chemicals listed. For accuracy, concentrations should be checked before, during, and after the addition of each salt. Use level household measures.

Foam on the Water Surface

Antifoaming agents are used to combat the formation of scum or foam on the water surface. Foam buildup during transport interferes with the observation of fish behavior and physical condition, and it may inhibit or otherwise compromise gas exchange.

An example of an antifoaming agent is DeFoam FG-10, which is used at 0.13 to 1.3 ounces (3.8 to 38 mL) per 100 gallons (379 L) of water. Another antifoaming agent is Aqui-S Aquatic Antifoam, which is used at 4 to 8 drops per 100 gallons (379 L) of water. Both are nontoxic and comply with FDA Regulation 21 CFR 173.340, which covers secondary direct food additives used as defoaming agents and allows concentrations of up to 10 mg/L of the active silicone in foods. Several other antifoaming agents are available; make sure they follow FDA guidelines.

Dissolved Oxygen

When fish are crowded, stressed, and excited, water quality can deteriorate rapidly. Therefore, oxygen is an important limiting factor in fish transport. Proper aeration equipment and careful monitoring before and during loading, in transit, and at unloading sites will ensure adequate concentrations (see SRAC Publication No. 390, *Transportation of Warmwater Fish: Equipment and Guidelines*).

Heavily loaded tanks require pure oxygen flow rates of 3 to 6 L/minute, although the rates can vary by species. Actual flow rates will vary from load to load and must be adjusted up or down accordingly. Take care to avoid supersaturating—forcing more oxygen into the water than it usually holds—the transport water with oxygen. Supersaturation could result in excessive oxygen use and dead or injured fish. Dissolved oxygen concentrations in water are determined by water temperature, local altitude, and salinity. For example, 100 percent saturation with dissolved oxygen in 68°F (20°C) water at sea level and 0 salinity would be 8.84 ppm. The saturation concentration decreases as water temperature, elevation, and salinity increase. Using pure oxygen (90 to 100 percent) versus atmospheric oxygen (about 21 percent) can cause higher oxygen concentrations to dissolve in water than are possible naturally. Supersaturating the water with oxygen can interfere with the fish's ability to process excess oxygen taken up by the gills. Excess oxygen may concentrate in the blood, causing "gas bubble disease," which may be lethal in severe cases. To ensure that each tank has the proper dissolved oxygen concentration (Table 5), the driver should check the dissolved oxygen levels often using a dissolved oxygen meter throughout the trip. Oxygen flow rates should be changed when problems develop.

Table 5. For the following temperatures, ranges of dissolved oxygen in freshwater transport tanks recommended by temperature.

Temperature °F (°C)	Dissolved oxygen (mg/L or ppm)
60 (15.6)	6.4–9.9
65 (18.3)	6.2–9.5
70 (21.1)	5.8–8.9
75 (23.9)	5.4–8.4
80 (26.7)	5.2–8.0

Carbon Dioxide

Although carbon dioxide will accumulate during transport, any adverse effects can be reduced by high oxygen concentrations, air circulation, and water agitation. However, fish mortalities can occur if the oxygen concentrations in the tank compartment become supersaturated. Also, if the transport tank is sealed tightly, carbon dioxide can build up, resulting in fish anesthetization or mortalities.

Ammonia

Ammonia can increase in hauling situations and is not removed by agitation. Fasting the fish before transport, using clean water, and lowering water temperature all help reduce ammonia. The pH of hauling water should be 7 to 7.5; higher pH increases the toxicity of unionized ammonia. Well-buffered water helps keep pH in balance. The addition of ammonia-neutralizing agents, such as ChlorAm-X®, is needed when hauling larval or juvenile fish for 4 hours or more, or during transportation in bags. An ammonia-neutralizing agent helps maintain water quality and reduces the chance of ammonia toxicity.

Temperature

Temperature is critical because it influences other water-quality variables. For example, water temperature is important in dissolved oxygen dynamics and consumption rates by fish. Cooling the water reduces metabolism rates (oxygen consumption) and increases the oxygen saturation in the water. Maintain oxygen concentrations at 6 to 7 ppm; higher concentrations may benefit extended trips.

Inadequate acclimation (tempering) for temperature differences during loading or unloading will stress or kill fish. Unfortunately, this practice is rarely done. Some species are susceptible to temperature shock, while others are hardy. Smaller fish are more sensitive than larger ones. The rule of thumb for freshwater fish is that they should be tempered for at least 20 minutes for each 10°F (5.6°C) difference in water temperature. Marine fish are more susceptible to rapid changes in water quality and should be tempered at a much slower rate than freshwater fish.

To lower water temperature by about 10°F (5.6°C), use ice at 0.5 pounds (0.23 kg) per gallon (3.78 L) (Fig. 2). Avoid using ice made from chlorinated drinking water, as chlorine is toxic to many fish species. Lowering the temperature during transport calms the fish, reduces their metabolic rate, and increases the oxygen saturation concentrations in the water. For short trips, the hauling temperature should be similar to the water at the destination. Tempering can begin several hours before arrival for trips longer than 8 to 12 hours.

It is advisable to mix receiving water with hauling water before releasing fish into a pond. This tempering is recommended if the pH difference is one or more units or the temperature difference is more than 10°F (5.6°C).

Figure 2. Adding ice to the hauling tank to reduce water temperatures.

When shipping fish in bags, as described under "Loading Rates for Shipping Fish in Boxes" above, the water temperature can be maintained by using blocks of ice or ice packs. Ice packs are placed in the box next to the air space in the bag. Placing the ice packs under the bag or on the sides next to the water can cause the temperature to decrease, which sometimes results in fish mortality.

Tips on Transportation of Select Species

Research is limited on the transportation of warmwater fish. However, the following guidelines for a few select species are helpful when transporting fish.

Channel Catfish and Their Hybrids

Channel catfish and their hybrids transport well and are easier to temper when transported at 60°F (15.6°C) in summer and 45 to 50°F (7.2 to 10°C) in winter. Extreme caution is required if fingerlings under 3 inches are transported above 70°F (21°C). Channel catfish virus disease threatens fingerlings at high temperatures.

Hardness and alkalinity values above 75 ppm (mg/L) are recommended for hauling tank water. Salt is beneficial at 0.2 to 1 percent (2,000 to 10,000 mg/L). Fry 3 to 7 days old can be transported in double-layered plastic bags at rates up to 15,000 fry per gallon (3.785 L) of water. Fry 7 to 14 days old can be loaded at 7,000 per gallon (3.785 L) for an 8-hour trip at 70°F (21°C). Fill the remaining volume in the bag with compressed pure oxygen and close tightly to prevent gas leakage. Bags should have a flat bottom with four corners. Place the bag in a cardboard box or ice cooler. In warm weather, add ice packs around the air-filled portion of the bag to help maintain temperatures.

Fry transport well for up to 24 hours. On delivery, temper the fry by placing a plastic bag in a tub of pond water and waiting about 30 minutes for the temperatures to equalize. Do not place the bags in direct sunlight. On farms, catfish fry are transported from hatcheries to ponds in small transport boxes of 50 to 100 gallons (189 to 378.5 L). Use diffused oxygen, not agitators. Do not overcrowd the transport boxes with fry. If the fry crowd to the surface, the fish load is excessive.

To haul egg masses in tanks, place them in a soft mesh bag suspended from a floating Styrofoam collar. This provides good water circulation around the egg mass. Although broodfish can be transported, special care is required during the spawning season. Anesthetize the broodfish or place them in burlap bags to prevent fighting.

Catfish eggs and fry can also be shipped in plastic bags with 65°F (18°C) water and pure oxygen. Two to three egg masses per plastic shipping bag work well. Do not ship eggs that may hatch during transit. A reasonable but conservative loading rate (24-hour transport) for channel catfish fry is 0.5 pounds of fry to each gallon (0.227 kg fry/3.785 L) of bagged water (Table 3). There are about 10,000 catfish fry to the pound (454 g). Two gallons (7.57 L) of water would be required to ship 10,000 channel catfish fry on a 24-hour trip [½ pound fry/gal × 2 gal × 10,000 fry/pound (0.227 kg fry/3.785 L × 10,000 fry/454 g)]. Ice or freezer gel packs can be added to an insulated shipping container (ice chest) to help keep the water temperature close to 65°F (18°C).

Shipping water should have a pH ranging from 7 to 8, bicarbonate alkalinity between 100 and 200 mg/L, and calcium hardness of 125 to 250 mg/L. Adding 0.2 to 0.5 percent (2000 to 5000 ppm) sodium chloride [table salt, 11/4 to 3 teaspoons per gallon (8.1 to 19.5 g)] is the standard recommendation for fry and small juvenile catfish.

Table 6 provides guidelines for transporting catfish fingerlings and near food-sized fish. Numbers are pounds of fish per gallon of water at 65°F (18°C). Adjustments for other conditions: Increase the loading rate by 25 percent for each drop of 10°F below 65°F (18°C) or if pure oxygen is used; decrease the loading rate by 25 percent for each increase in 10°F above 65°F (18°C).

Figure 3. Workers getting ready to load channel catfish from a pond into hauling tanks.

As a rule of thumb, 5 pounds (2.3 kg) of 1- to 2-pound (0.5 to 0.9 kg) catfish can be loaded per gallon of water using liquid oxygen at a water temperature of 65°F (18°C) (Fig. 3).

Baitfish

The three most cultured baitfish in the United States are golden shiners, goldfish, and fathead minnows. Golden shiners are the most challenging baitfish to transport because of their large, easily shed scales. When several scales are lost, most injured fish will die during or soon after transport. They are also easily excited and will jump from a container upon the least bit of vibration. It is recommended to load the fish into hauling tanks while in water (Fig. 4). These three baitfish haul best at 60°F (16°C) and a rate of 1 to 2 pounds (0.5 to 0.9 kg) per gallon. For hauls of less than 2 hours, this rate can be exceeded.

Some species of bait minnows are more tolerant than others to handling. Golden shiners are incredibly delicate when temperatures exceed 60°F (16°C) and often suffer delayed mortalities when suddenly transferred from 60°F (16°C) to 75°F (24°C) water, which is the typical temperature in retail holding vats during the summer. Any time

Table 6. Pounds of channel catfish per gallon of 65°F (18°C) water that can be transported for various times.

Pounds per 1000 fish (kg per 1000 fish)	Average weight per fish pounds (g)	Transit time in hours		
		8	12	16
0.1 (0.05)	0.0001 (0.05)	0.2 (91)	0.2 (91)	0.20 (91)
1.0 (0.45)	0.001 (0.5)	1.25 (567)	1.00 (454)	0.70 (318)
2.0 (0.91)	0.002 (0.9)	1.75 (794)	1.65 (748)	1.25 (567)
4.0 (1.81)	0.004 (2)	2.20 (998)	1.75 (794)	1.50 (680)
8.0 (3.62)	0.008 (4)	2.95 (1338)	2.20 (998)	1.80 (816)
20 (9.0)	0.02 (9)	3.45 (1565)	2.50 (1134)	2.05 (930)
250 (113)	0.25 (113)	5.00 (2268)	4.1 (1860)	2.95 (1338)
500 (227)	0.50 (227)	5.90 (2676)	4.80 (2177)	3.45 (1565)
1000 (454)	1 (454)	6.30 (2858)	5.55 (2517)	4.80 (2177)

Figure 4. Loading baitfish into hauling tanks.

the difference is more than 5°F (2.8°C), the fish on the truck should be tempered to decrease mortalities. Golden shiners haul well at 2 pounds (0.9 kg) per gallon (3.785 L) in salt solutions of less than 0.2 percent (2000 ppm). Adding 1 cup (212 g) of baking soda (sodium bicarbonate) and 1.7 pounds (771 g) of table salt (sodium chloride) or calcium chloride per 100 gallons (378.5 L) will reduce stress and correct differences in alkalinity and pH.

Golden shiners can tolerate a temperature drop of 15°F (8.3°C), but fathead minnows and bait-sized goldfish require gradual tempering. Haul goldfish and fathead minnows in water at the same temperature as the pond for short hauls. Goldfish can be shipped at 1 pound (0.5 kg) per gallon (3.785 L) in summer and 2 pounds (0.9 kg) per gallon (3.785 L) in winter. Smaller goldfish transport well at 1.5 pounds (0.68 kg) per gallon (3.785 L) in winter at 55°F (13°C) with liquid oxygen supplied at 5 liters per minute. Fish should be held in vats at least 24 hours before transport. Young goldfish less than 3 inches are very soft and delicate to handle. Minnows can be successfully hauled with agitators and pure oxygen at 1 pound (0.45 kg) per gallon (3.785 L) during cooler months and 0.7 pounds (0.32 kg) per gallon (3.785 L) in summer.

Goldfish are often shipped in plastic bags. Bag sizes should be 18 inches (45.7 cm) wide, 32 inches (81.3 cm) long, and 0.003 inches (3 mil) thick. If transportation time is less than 24 hours, 5 to 6 pounds (2.3 to 2.7 kg) of goldfish can be shipped. For longer transport times, place
6 pounds (2.7 kg) of goldfish in 2 gallons (7.6 L) of good-quality water.

Tropical or Ornamental Fish

Tropical fish include many species of fish in the aquarium trade. These fish are generally shipped in plastic bags in boxes. Tropical fish are usually fasted for 48 hours before transporting. Salt and anesthetics are added to the water, which is reduced to 77°F (25°C). Some species can tolerate lower temperatures. Loading rates are 0.4 to 0.7 pounds (181 to 318 g) per gallon (3.785 L). Water hardness above 100 mg/L is preferred. Table 5 provides the number of fish per bag in two gallons (7.6 L) of water for common freshwater aquarium fish.

Striped Bass and Its Hybrids

Striped bass and its hybrids can be grown in either fresh or brackish water, but these fish are very sensi-

Table 7. Various-size common ornamental fish shipped in a full square-bottomed bag measuring 15.5 inches × 14.5 inches × 22.5 inches (39.4 cm × 36.8 cm × 57.1 cm) with 2 gallons (7.6 L) of water.

Fish group	Fish size inches (cm)	Quantity per bag	Examples
Tetras	1–1⅛ (2.5–2.9)	400	Glow light, white clouds
	1⅛–11/2 (2.9-3.8)	300	Black neons, serpae, lemon, head light, tail light
	11/2–21/2 (3.8-6.4)	200–250	Diamonds, black, phantoms, Columbians
Barbs	⅝–¾ (1.6–1.9)	400	
	¾–1½ (1.9–3.8)	250	Tiger
	1½–2 (3.8–5.1)	150	
Gouramis	1¾–2 (4.4–5.1)	125–150	
	2–2½ (5.1–6.4)	75–100	
Angelfishes	¾ (1.9) or "5-cent size"	150	
	1 (2.5) or "25-cent size"	75–100	
	2–2½ (5.1–6.4) or "silver dollar size"	20–25	
Livebearers	1½–2 (3.8–5.1)	300	Platies, mollies
	2–2½ (5.1–6.4)	250	Swordtails

tive to handling and should always be moved in water whenever possible. Often striped or white bass must be obtained from hatcheries or natural stocks in the wild. Recent studies indicate that fry 5 to 30 days old are not as sensitive to netting and light shock as previously believed.

Harvest striped bass when the pond water is cool and not muddy. Transfer the fish immediately to a container with oxygenated water and 4 to 8 mg/L salt. Water hardness above 75 mg/L is recommended for striped bass and hybrid striped bass when transporting. Water hardness below 30 mg/L results in high mortality rates.

Loading rates for striped bass and hybrid striped bass include:

- 1,000 fish per pound at 0.15 pounds (68 g) per gallon (3.785 L) for 10 hours
- 5 fish per pound (454 g) at 1.5 pounds (680 g) per gallon (3.785 L) for 10 hours
- 0.75 pounds (340 g) per gallon (3.785 L) for 15 hours
- 500 fish per pound (454 g) at 0.5 pounds (227 g) per gallon (3.785 L) for 24 hours.

The optimum water temperature is 55 to 65°F (13 to 18°C), and a salinity of 4 to 8 ppt will reduce stress when fish are transported. Broodfish should be transported at 70 to 75°F (21 to 24°C). Striped bass fry at least 5 days old appear to survive transport and stocking better than younger fish. Place 40,000 fry per gallon (3.785 L) in oxygenated plastic bags. For fry, temper gradually at a rate of one-half hour per 3°F (1.7°C) difference in temperature. Do not haul fish smaller than 2 inches (5 cm) in units using agitators because of possible mechanical injury.

Suggested loading rates for 2-inch (5 cm) striped bass include:

- 0.5 pounds (227 g) per gallon (3.785 L) for 1 to 4 hours
- 0.33 pounds (150 g) per gallon (3.785 L) for 4 to 8 hours
- 0.25 pounds (113 g) per gallon (3.785 L) for more than 8 hours

Largemouth Bass

Harvest largemouth bass by seining after 3 days of fasting. Provide a resting period after harvest and before loading. Live haulers use 2 to 3 pounds (0.9 to 1.4 kg) of salt per 100 gallons (379 L; 2 to 4 ppt) for long-distance transport, but salt concentrations up to 8 pounds (3.6 kg) per 100 gallons (379 L; 9 ppt) can be used. Using additional salt additives of potassium chloride, potassium phosphate, and magnesium sulfate at concentrations similar to those in the blood of largemouth bass also helps reduce mortalities.

To prepare a salt solution containing the potassium and magnesium concentrations found in largemouth bass blood, mix the following concentrations in ounces in 1 gallon of water: 22.5 (5,950 ppm) sodium chloride, 0.95 (252 ppm) potassium chloride, 0.62 (164 ppm) potassium phosphate, 0.54 (143 ppm) magnesium sulfate, 0.57 (151 ppm) calcium chloride and 0.8 (210 ppm) sodium carbonate in distilled water. If you know the ion concentration of your water, the formula can be adjusted accordingly.

However, if largemouth bass are hauled using all the salts previously listed, they should be placed in water with similar salts and slowly acclimated to the receiving water over 2 to 3 days. Transport the fish in 15 ppm MS-222, and slowly reduce the water temperature to 61°F (16°C) over the first portion of transport. Use liquid oxygen and maintain dissolved oxygen concentrations at 7 ppm for short trips and 10 mg/L for trips longer than 8 hours. Keep dissolved oxygen below saturation, as significant mortalities can occur when water is supersaturated. Largemouth bass require tempering when they reach their destination. Largemouth bass may require up to 3 days to recover from hauling stress.

Food-sized largemouth bass are now transported to live markets throughout North America. Table 9 provides guidelines on loading densities based on water temperature and trip duration. These load-

Table 8. Maximum loading density of largemouth bass, bluegill, and other sunfishes per gallon of water transported between 10 and 16 hours at water temperatures ranging from 65 to 75°F (18 to 19°C).

Fish size in inches (cm)	Number of fish per pound (kg)	Number of fish per gallon (L)	Loading rates of fish in pounds per gallon (g/L)
1 (2.5)	1,000 (2,200)	333 (1,265)	0.33 (40)
2 (5.0)	400 (880)	200 (760)	0.50 (60)
3 (7.5)	100 (220)	67 (255)	0.66 (80)
4 (10.0)	25 (55)	25 (67)	1.0 (120)

Table 9. Maximum loading densities of food-sized largemouth bass weighing 1 to 2 pounds (0.45 to 0.9 kg) average individual weight based on water temperature and trip duration.

Water temperature in °F (°C)	Trip duration hours		
	0–14 h Pounds/gallon (g/L)	15–20 h Pounds/gallon (g/L)	21–24 h Pounds/gallon (g/L)
37–47 (3–8)	3.00 (360)	2.25 (270)	1.50 (180)
48–56 (9–13)	2.25 (270)	1.50 (180)	1.13 (135)
57–65 (14–18)	1.50 (180)	1.13 (135)	0.75 (90)

ing densities can be adjusted. For example, for every 6-hour increase in transport time, loading rates should be decreased by 25 percent. Likewise, for every 10°F (5.6°C) increase in water temperature, loading rates should be reduced by 25 percent.

Bass sac-fry 1 to 3 days old can be shipped for 3 to 4 days in plastic bags at 11,400 fish per gallon (3.785 L). Square-bottomed bags are preferable. Do not add salt to the water when transporting fry. Table 5 recommends loading densities for largemouth bass into hauling tanks for trips less than 16 hours.

Bluegill, Redear Sunfish, Hybrid Bluegill, and Crappie

Table 8 provides guidelines for transporting bluegill, redear sunfish, hybrid bluegill, and other sunfish for up to 16 hours. These fish are usually hauled with 0.3 to 0.5 percent (3,000 to 5,000 ppm) salt.

Red Drum (Redfish)

Red drum should be fasted for 1 to 2 days before harvest. Haul red drum in water no more than 37°F (3°C) lower than the water they are harvested from. Do not haul red drum at water temperatures (either harvest or hauling water) above 88°F (31°C) because of the low oxygen capacity of warm water. Also, to assist with stress and osmoregulation, haul red drum at 3 to 5 ppt lower salinity than the water they were harvested from.

Do not haul red drum in fresh water. Loading rates for 1- to 2-inch (2.5 to 5 cm) fish include 0.33 pounds (0.15 kg) per gallon (3.785 L) for less than 8 hours of transport and 0.25 pounds (0.11 kg) per gallon (3.785 L) for longer trips. One-inch (2.54 cm) fish have also been transported at 0.1 pounds (45 g) per gallon (3.785 L) at 80°F (27°C) in 32 ppt salinity for 5 hours. Fingerlings 5 to 8 inches (12.7 to 20.3 cm) transport well in salinities from 4 to 32 ppt.

Tilapia

Tilapia fingerlings are often shipped in plastic bags. Tilapia fingerlings should be fasted for 24 hours and shipped in 4 mg/L salt in a blue transportation bag. The combination will allow for shipping fingerlings for up to 48 hours safely. Use ice as described previously. Tilapia of 9 pounds (4.1 kg) per 1,000 fish can be shipped in plastic bags at up to 5 pounds (2.3 kg) per gallon (3.785 L) at 60°F (16°C) for 24 hours. Tilapia transported for live market sales are held off feed for 3 to 5 days to prevent water fouling. Water temperatures are slowly lowered to 74°F (23°C). Tilapia are hauled in water at densities of 1.4 to 1.87 pounds/gallon (168 to 224 g/L). Sodium chlo-ride is added at 6.5 pounds (2.95 kg) per 100 gallons (378.5 L) of water. To reduce stress in the fish, oxygen concentrations of 4.0 mg/L should be maintained in hauling water. Using these methods, tilapia can be safely transported for up to 18 hours or more with little mortality and can be held for live sale for up to 1 week after harvest.

Grass Carp and Triploid Grass Carp

Grass carp and triploid grass carp are used in aquatic weed control and transported in shipping boxes or hauling trucks. Most states now require grass carp to be triploid (having three sets of chromosomes and therefore essentially sterile) to bring them into the state or stock them in ponds.

Grass carp are generally hauled only in the spring and winter. During the hotter months of the year, grass carp are very sensitive to seining and hauling stress. Most grass carp are transported at 65°F (18°C) using 2 pounds (907 g) of salt per 100 gallons (378.5 L). Loading densities average 2 pounds (907 g) per gallon (3.785 L). For long hauls of 20 hours and during the winter, that is 200 to 300 10-inch (25-cm) fish per 100 gallons (378.5 L). For shorter hauls of 12 hours, loading densities are 250 10-inch (25-cm) fish or 200 12-inch (30.5-cm) fish per 100 gallons (378.5 L) of water. Grass carp are sedated with 20 ppm of MS-222 to load into the hauling tank but not sedated during transport.

Grass carp sac fry and small fingerlings can be shipped in boxes. Table 10 provides the numbers for fish depending on temperature and distance.

Table 10. Numbers of sac fry and small fingerling grass carp that can be transported per gallon of water in a polyethylene bag. The bag should be filled with 5 gallons (20 L) of water and 8 gallons (30 L) of oxygen.

	68°F (20°C)				79°F (26°C)			
Duration in hours	**4**	**8**	**12**	**24**	**4**	**8**	**12**	**24**
Sac fry (in thousands)	1.5	50	40	30	40	30	25	15
Fingerlings 2–3 cm	10	8	6	5	8	6	4	3

Summary

It is important to know the specifics (water quality requirements, susceptibility to handling, etc.) of the species you are transporting. If guidelines for those species are not provided, use the general loading densities as a starting point. It is best to be conservative until you have more experience in hauling the species of interest.

Load fish carefully into transport units. Delicate fish should be given mild sedation while in the holding vat. Increase the oxygen supply while fish are being loaded. Check dissolved oxygen in the hauling unit routinely to ensure concentrations near saturation.

Do not overload dip nets or loading baskets. Fish should be handled rapidly, and delicate, scaled species should be kept in water whenever possible. Avoid the warmest times of the day and direct, bright sunlight. Minimize the time out of the water on windy days when the drying effect is greatest. Avoid injuries (broken or damaged fins and scale loss), which provide sites for opportunistic infections. Adverse effects from stress are additive and cumulative. Salt or an anesthetic in the hauling water can minimize stress.

Always avoid temperature shock. Any sudden temperature difference of more than 10°F can harm fish, particularly smaller ones. In addition, cold winter air and wind chill factors can cause temperature shock when fish are moved in nets.

Suggested Readings

Crosby, T.C., J.E. Hill, C.V. Martinez, C.A. Watson, D.B. Pouder, and R.P.E. Yanong. 2021. Preparation of ornamental fish for shipping. UF/IFAS Fact Sheet FA-120. Available at: *https://edis.ifas.ufl.edu/pdf/FA/FA120/FA120-Dslvi8y5pl.pdf*

Dorman, L. 2002. Aquaculture producer's quick reference handbook. University of Arkansas Cooperative Extension Program MP435.

McCraren, J.P., and R.M. Jones. 1978. Suggested approach for computing and reporting loading densities for fish transport units. The Progressive Fish Culturist 40:169.

Orina, P.S., J.M. Munguti, M.A. Opiyo, and H.C. Karisa. 2014. Optimization of seed and broodstock transport densities for improved survival of cultured Nile tilapia (*Oreochromis niloticus,* L. 1758). International Journal of Fisheries and Aquatic Studies 1:157–161.

Piper, R.G., I.B. McElwain, L.E. Orne, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1986. Fish hatchery management. Fourth edition. Bethesda, MD: American Fisheries Society and the U.S. Fish and Wildlife Services.

Tidwell, J.H., S.D. Coyle, and L.A. Bright. 2019. Largemouth bass aquaculture. Sheffield, UK: 5 M Publishing.

Tomaso, J.R., and G.J. Carmichael. 1988. Handling and transport-induced stress in red drum fingerlings (*Sciaenops ocellatus*). Pages 133–138 in C.R. Arnold, G.J. Holt, and P. Thomas, editors. Red drum aquaculture: Proceeding of a symposium on the culture of red drum and other warm water fishes. Contributions in Marine Science, Supplement to volume 30. Austin, TX: The University of Texas at Austin.

Tucker, J.W. 1998. Marine fish culture. Boston, MA: Kluwer Academic Publishers.

Wedemeyer, G. 2001. Fish hatchery management. 2nd edition. Bethesda, MA: American Fisheries Society

Wilson, A.J. Distribution units for warm-water fish. The Progressive Fish Culturist 12:211–213.

Wurts, W.A. 1995. Using salt to reduce handling stress in channel catfish. World Aquaculture 26(3): 80–81.

Wurts, W.A. 1993. Transporting channel catfish fry and fingerlings in plastic bags. World Aquaculture 24(3):85.

Wynne, F., and W. Wurts. 2009. Live hauling channel catfish. Kentucky State University, Division of Aquaculture, Cooperative Extension Program.

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2016-38500-25752. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

USDA United States Department of Agriculture National Institute of Food and Agriculture

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 2016-38500-25752 from the United States Department of Agriculture, National Institute of Food and Agriculture.