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Estimation of Tracy Fish Collection Facility Fish-Haul Truck Biomass Capacity

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14. ABSTRACT
Fish-haul trucks used during salvage operations at the Tracy Fish Collection Facility (TFCF; operated by the Bureau of Reclamation) were evaluated (with no fish in the truck tanks) to estimate fish biomass capacity based on tank volume, oxygen (O_2) and compressed air system capabilities, and published fish O_2 consumption, total ammonia nitrogen (TAN) production, and carbon dioxide production rates. Results suggest O_2 and compressed air systems on the fish-haul trucks are adequate for short-duration transport (approximately 1 h) of fish from the TFCF to release sites. Biomass capacity of the fish-haul trucks appeared to be limited by TAN production and was estimated to be 310.8 kg (loading density = 31.4 g/L). It was conservatively estimated that the fish-haul trucks can effectively transport between 6,283 and 3,486,100 fish, depending on size. For certain sizes of fish, carrying capacity estimates from this study were lower than estimates from updated fish transport tables currently used at the TFCF. Based on this, it is recommended that fish transport tables used at the TFCF be further updated using TAN-limited carrying capacity estimates from this study. Alternatively, methods to remove excessive TAN from water or reduce ammonia toxicity during fish transport should be considered.

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Tracy Fish Facility Improvement Program
California-Great Basin · Interior Region 10

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The U.S. Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Disclaimer

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Executive Summary

The Tracy Fish Collection Facility (TFCF; operated by the Bureau of Reclamation) functions to salvage fish from Sacramento-San Joaquin River Delta (Delta) water exported by the C.W. "Bill" Jones Pumping Plant. After salvage, fish are maintained in holding tanks until being transferred to a fish-haul truck tank for transport back to the Delta. The schedule of fish transport is dependent on salvage rates, debris loading, and special status species procedures. To determine when transport is necessary due to accumulation of fish in holding tanks, fish transport tables are used to estimate the percent of a load that a total number of salvaged fish within a particular size class represents. Salvaged fish are transported from the TFCF to one of two release sites located near the confluence of the Sacramento and San Joaquin Rivers, away from the immediate influence of south Delta pumping facilities.

Maintenance of adequate dissolved oxygen (DO), total ammonia nitrogen (TAN), and carbon dioxide (CO_2) levels is necessary for fish health and survival during transport. Sutphin and Wu (2008) previously reported fish density (0.3–64.5 g of fish/L) and water quality parameters of concern (i.e., temperature, DO, CO_2 concentration, pH, total gas saturation, and TAN) in the fish-haul trucks generally remained within acceptable ranges throughout the period of fish transport at temperatures between 15.2–25.3 °C. In 2008 and 2010, respectively, new fish-haul trucks and updated fish transport tables were put into service at the TFCF. The current fish-haul trucks (9,914.0-L) were evaluated (with no fish in the truck tanks) to estimate biomass capacity based on fish-haul truck tank volume, oxygen (O_2) and compressed air system capabilities, and published fish O_2 consumption (from Sutphin and Myrick 2015), TAN production, and CO_2 production rates (from Sutphin and Hueth 2015). Published estimates of fish O_2 consumption were available for Delta Smelt (*Hypomesus transpacificus*), Chinook Salmon (*Oncorhynchus tshawytscha*), Striped Bass (*Morone saxatilis*), and Threadfin Shad (*Dorosoma petenense*), while published estimates of TAN and CO_2 production were available for Chinook Salmon, Striped Bass, and Threadfin Shad. Of these species, Threadfin Shad exhibited the highest maximum O_2 consumption, TAN production, and CO_2 production rates, which were used to develop biomass capacity estimates.

Operating only the O_2 system in the fish-haul trucks resulted in the highest rate of DO increase (0.46 mg/L/min). Simultaneous operation of the compressed air and O_2 systems resulted in the next highest rate of DO increase (0.32 mg/L/min), followed by operation of only the compressed air system (0.05 mg/L/min). Results suggest O_2 and compressed air systems on the fish-haul trucks are adequate for the short-duration transport (approximately 1 h) of fish from the TFCF to release sites. Biomass capacity of the TFCF fish-haul trucks appeared to be limited by TAN production and was estimated to be 310.8 kg (loading density = 31.4 g/L). It was conservatively estimated (using published fork length [FL; mm]-weight [g] relationships for Threadfin Shad from Gartz 2004) that the TFCF fish-haul trucks can transport between 6,283 (150 mm FL) and 3,486,100 (20 mm FL) fish, depending on fish size. For certain sizes of fish, carrying capacity estimates from this study were lower than estimates from updated fish transport tables currently used at the TFCF. Based on this, it is recommended that fish transport tables used at the TFCF be further updated to include TAN-limited carrying capacity estimates developed during this study. Alternatively, methods to remove excessive TAN from water or reduce ammonia toxicity during fish transport should be considered.

Introduction

The Tracy Fish Collection Facility (TFCF; operated by the Bureau of Reclamation [Reclamation]) is located at the head of the Delta-Mendota Canal, 4 km NE of the C.W. "Bill" Jones Pumping Plant (JPP) and 15 km NW of Tracy, California (Figure 1). The TFCF functions to salvage fish from Sacramento-San Joaquin Delta (Delta) water exported by the JPP. After salvage, fish are maintained in holding tanks (6-m wide x 5-m deep; Reclamation 1956) until being collected in a haul-out bucket (1544-L; 1.8-m inside diameter with a conical bottom from 0.9-m deep to 1.3-m deep; Reclamation 1956) and transferred to a fish-haul truck tank (9,914.0-L; 4.6-m long x 2.0-m wide x 1.2-m deep; Reclamation 2007, Reyes et al. 2018) for transport back to the Delta. The schedule of fish transport is dependent on salvage rates, debris loading, and special status species procedures (CDFW 2013). To determine when transport is necessary due to accumulation of fish in holding tanks, fish transport tables developed based on fish-haul truck tank volume, oxygenation capabilities, fish size (i.e., oxygen [O_2] consumption), and water temperature are used to estimate the percent of a load that a total number of salvaged fish within a particular size class represents. Salvaged fish are transported 34.3–42.8 km from the TFCF to one of two release sites (Antioch Fish Release Site or Emmaton Fish Release Site, respectively; Figure 1) located near the confluence of the Sacramento and San Joaquin Rivers, away from the immediate influence of south Delta pumping facilities (Sutphin and Wu 2008). Transport duration from the TFCF to the release sites is approximately 60 mins (mean = 59.4 mins; Sutphin and Wu 2008).

Maintenance of adequate dissolved oxygen (DO), total ammonia nitrogen (TAN; the sum of ammonium ions [NH_4^+] and un-ionized ammonia [NH_3; Wedemeyer 1996]), and carbon dioxide (CO_2) levels is necessary for fish health and survival during transport. Dissolved oxygen levels in the fish-haul trucks can affect the success of fish transportation as low DO levels can result in respiratory stress, which can affect swimming performance, equilibrium, and survival (Moyle and Cech 2004, Herbert and Steffensen 2005, Portz et al. 2006). On the contrary, excessive DO may contribute to total gas supersaturation (i.e., total gas saturation > 110%) and associated fish health issues (i.e., gas bubble disease [the formation of gas bubbles in the heart and other areas of the circulatory system]) that can ultimately lead to fish mortality (Wedemeyer 1996, Sutphin and Wu 2008). Total ammonia nitrogen can reach toxic levels in closed transport systems, as fish continuously produce TAN as a primary byproduct of protein metabolism and water consumption (Wedemeyer 1996, Murphy and Willis 1996). Short-term exposure to elevated TAN levels can cause increased gill ventilation, erratic and quick movements, loss of equilibrium, coughing, convulsions, reduced foraging, and mortality in fishes (Meade 1985, Russo and Thurston 1991, Portz et al. 2005). Dissolved CO_2 can increase as a product of fish respiration. Excessive dissolved CO_2 concentrations may cause increases in plasma CO_2 (hypercapnia), which results in a decrease in blood pH (respiratory acidosis) and can provoke vaso-constrictions, increased blood pressure, changes in aortic blood pressure (species-dependent), unconsciousness, and mortality (Crocker et al. 2000, Perry and Gilmour 2002, Portz et al. 2006, Wu and Bridges 2014).

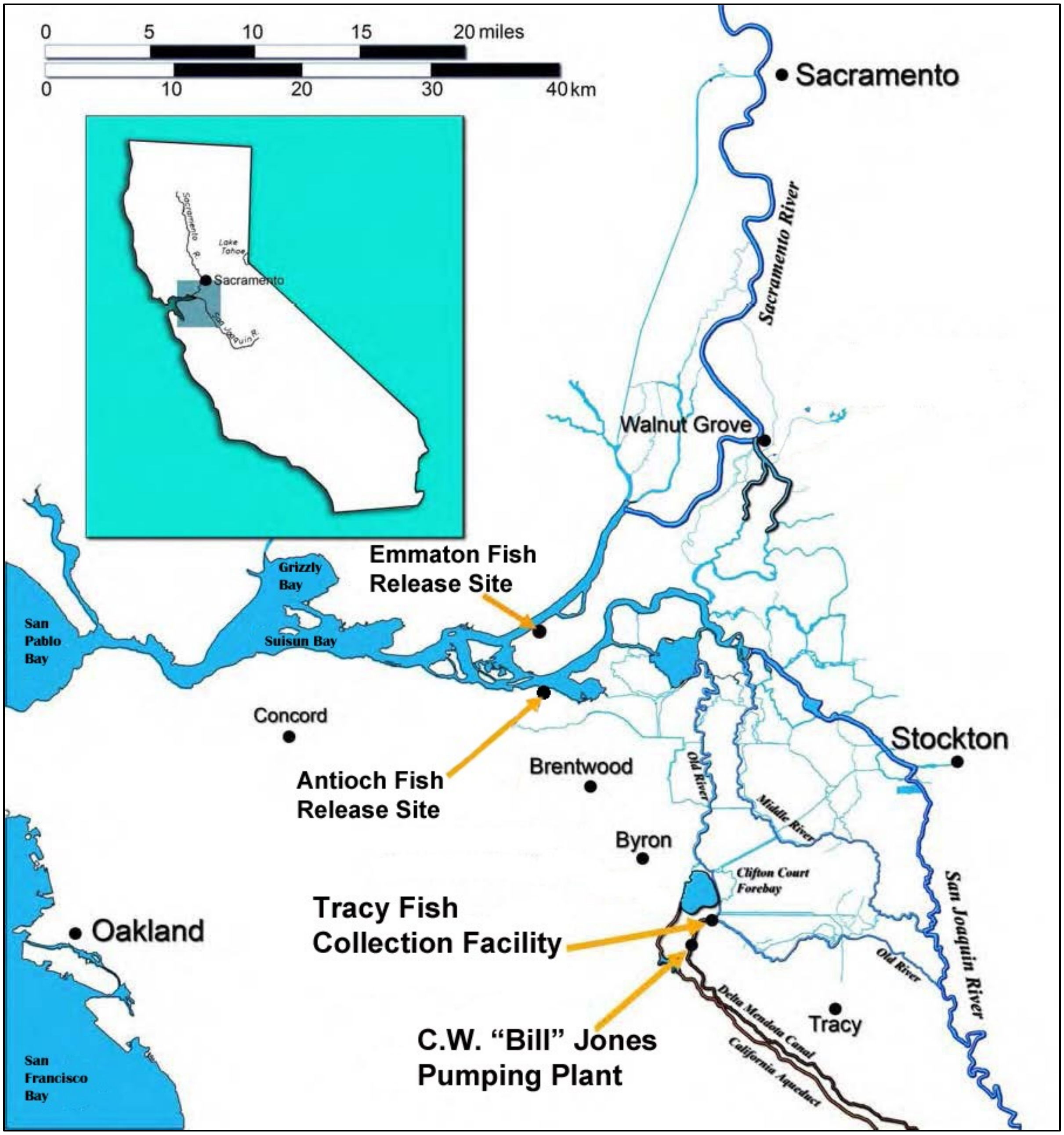

Figure 1.—Map of the Sacramento-San Joaquin River Delta showing locations of the Tracy Fish Collection Facility, C.W. "Bill" Jones Pumping Plant, Antioch Fish Release Site, and Emmaton Fish Release Site.

There have been 4 generations of fish-haul trucks used to transport fish to release sites after salvage at the TFCF. The first-generation of fish-haul trucks (late 1957–early 1960s) had a 3,785.4-L tank, the second-generation fish-haul trucks (early 1960s–1990) had 5,678.1-L tank, the third-generation fish-haul trucks (1990–2008) had a 7,570.8-L tank, and the current (fourth-generation) fish-haul trucks (2008-present) have a 9,914.0-L tank (Reyes et al. 2018). The first-, second-, and third-generation fish-haul trucks were equipped with O_2 systems only, while the current (fourth-generation) fish-haul trucks are equipped with a compressed air system in addition to an O_2 system (Reyes et al. 2018). In addition to reducing the cost and maintenance associated with the use of

O_2 cylinders, the inclusion of a compressed air system in the current fish-haul trucks potentially reduces excessive O_2 build-up in the truck tanks when it is used instead of, or in combination with, the O_2 system (pure O_2) and may prevent health issues related to supersaturation of the water when fish densities are low.

Fish transport tables were originally developed by Bates et al. (1960) for use in the first-generation of fish-haul trucks (i.e., 3,785.4-L tank with only an O_2 system) based on fish-haul truck tank volume, oxygenation capabilities, fish species and size [i.e., O_2 consumption], water temperature, and fish-haul durations of between 1-1.75 h (Bates et al. 1960; Appendix 1 [Tables A1-1–A1-6]). The fish transport tables provided by Bates et al. (1960) were updated in 2010 for use in a 9,085.0-L fish-haul truck tank with fish-haul durations of approximately 1 h (updated fish transport tables; Appendix 2 [Tables A2-1–A2-6]; Reyes et al. 2018). The updated fish transport tables are currently being used at the TFCF with the fourth-generation trucks.

Sutphin and Wu (2008) reported fish density (0.3–64.5 g of fish/L) and water quality parameters of concern (i.e., temperature, DO, CO_2 concentration, pH, total gas saturation, and TAN) in the third-generation fish-haul trucks (equipped with only O_2 systems; Figure 2) generally remained within acceptable ranges throughout the period of fish transport at temperatures between 15.2–25.3 °C when using the fish transport tables provided by Bates et al. (1960). Since then, the fourth-generation fish-haul trucks (Figure 2) and updated fish transport tables have been put into service at the TFCF. To promote fish survival during truck transport to release sites, the current (fourth-generation) fish-haul trucks (with a compressed air system in addition to an O_2 system) were evaluated (with no fish in the truck tanks) to estimate biomass capacity. Biomass capacity estimates were developed based on fish-haul truck tank volume, maximum O_2 and compressed air system output, and published O_2 consumption (from Sutphin and Myrick 2015), TAN production, and CO_2 production rates (from Sutphin and Hueth 2015) of common fish species transported from the TFCF to release sites.

Figure 2.—Third-generation fish-haul truck (7,570.8-L; equipped with oxygen [O_2] system only) historically used (1990–2008) to transport fish from the Tracy Fish Collection Facility (TFCF) to fish release sites (top) and fourth-generation fish-haul truck (9,914.0-L; equipped with compressed air and O_2 systems) currently used (2008–present) to transport fish from the TFCF to fish release sites (bottom).

Methods

The rate of DO increase in a fish-haul truck tank while operating the compressed air system only, the O_2 system only, and both the compressed air and O_2 systems simultaneously was determined with maximum sustainable operating gas flow (approximately 8 L/min) through the truck diffusers (Model MBD600; Point Four Systems, Inc., Coquitlam, BC Canada). The maximum sustainable gas flow through the truck diffusers was limited by operating pressure of the compressed air and O_2 systems, which were set to 40 psi based on required bubbling pressure and maximum operating pressure of the diffusers (i.e., bubbling pressure = 25–35 psi, maximum operating pressure = 50 psi). Sampling was completed during times when the Delta water temperatures were ≥ 22.0 °C (i.e., June-September) because the warmer water likely resulted in the lowest rate of DO increase and, in combination with maximum published estimates of fish O_2 consumption, likely yielded a conservative estimate of biomass capacity for the current fish-haul trucks at the TFCF based on O_2 and compressed air system capabilities. In addition, increased numbers of fish have historically been salvaged at the TFCF when Delta water temperatures are within or near this range (CDFW 2020).

All replicates were completed with an operational fourth-generation (2008–present), stationary fish-haul truck. To simulate standard operating procedures for fish-hauls at the TFCF, the fish-haul truck tank was filled completely with water containing 8.0 mg/L salt using a salt-mixing venturi. The addition of salt to fish-haul truck tanks was important because oxygen solubility in water decreases exponentially as salt levels increase (Benson and Krause 1984, Hach 2020). In an effort to develop a comprehensive rate of O_2 rise for each system or combination of systems, nitrogen gas was injected into the water from a pressurized cylinder using micro bubble diffusers (Model MBD300; Point Four Systems, Inc., Coquitlam, BC Canada) until a DO concentration of 4.0 mg/L, or under, was reached (measured with a YSI Professional 2030 instrument [Pro2030; YSI Incorporated, Yellow Springs, Ohio]). The appropriate gas system, or combination of gas systems, was then turned on and set to 40 psi for all replicates. Oxygen measurements were taken with a Pro2030 instrument and were obtained from the mid-water column every 2 min for a 60 min period. The water in the fish-haul truck tank was continuously mixed during this period using a 0.5 hp submersible pump (Model 4HF; Tsurumi, Inc., Glendale Heights, Illinois) to simulate the mixing associated with water sloshing during transport and to obtain uniform O_2 distribution within the tank. Atmospheric and ambient Delta water temperatures were measured at the beginning and end of each replicate using an Acu-Rite indoor/outdoor digital thermometer (Model 02067M; Chaney Instrument Co., Lake Geneva, Wisconsin) and a Pro2030 instrument, respectively.

Data Analyses

Scatter plots were generated showing the change in DO over time in the TFCF fish-haul trucks when using only the compressed air system, only the O_2 system, and simultaneous operation of both the compressed air and O_2 systems (with no fish in the truck tanks; Excel 365; Microsoft Corporation, Redmond, Washington). Linear trend lines were then applied to the scatter plots to obtain equations for DO increase over time under each operational condition. Linear trend lines were used to simplify data analysis as a constant rate of DO increase was obtained for each system or combination of systems.

Published estimates of fish O_2 consumption from Sutphin and Myrick (2015) were used, along with fish-haul truck tank volume and measured rates of DO increase, to estimate biomass capacity of the TFCF fish-haul trucks while operating the compressed air system only, O_2 system only, and both the compressed air and O_2 systems simultaneously. Sutphin and Myrick (2015) developed O_2 consumption estimates for Delta Smelt (*Hypomesus transpacificus*), Chinook Salmon (*Oncorhynchus tshawytscha*), Striped Bass (*Morone saxatilis*) and Threadfin Shad (*Dorosoma petenense*), which are either Endangered Species Act listed species encountered at the TFCF (Delta Smelt and Chinook Salmon) or are amongst the most common and abundant fish species salvaged at the facility (Striped Bass and Threadfin Shad). Of these species, Threadfin Shad exhibited the highest maximum O_2 consumption rate (0.19 mg O_2/g of fish/hour at 28 °C) which was used to develop biomass capacity estimates for the compressed air and O_2 systems in the TFCF fish-haul trucks. It is assumed that biomass capacity estimates developed during this study based on Threadfin Shad O_2 consumption are applicable to all fish species salvaged at the TFCF.

Published estimates of fish TAN and CO_2 production rates from Sutphin and Hueth (2015) were used along with fish-haul truck volume to estimate biomass capacity of the TFCF fish-haul trucks based on TAN and CO_2 production. Sutphin and Hueth (2015) developed TAN and CO_2 production rate estimates for Chinook Salmon, Striped Bass and Threadfin Shad, which are either Endangered Species Act listed species encountered at the TFCF (Chinook Salmon) or are amongst the most common and abundant fish species salvaged at the facility (Striped Bass and Threadfin Shad). Threadfin Shad were estimated to have the highest TAN and CO_2 production rates of all species tested by Sutphin and Hueth (2015). Therefore, maximum Threadfin Shad TAN production rates (0.54 mg TAN/g of fish/hour) and CO_2 production rates (0.7 mg CO_2/g of fish/hour) from Sutphin and Hueth (2015) were used to estimate biomass capacity of the TFCF fish-haul trucks based on TAN and CO_2 production. It is assumed that biomass capacity estimates developed during this study based on Threadfin Shad TAN production and CO_2 production rates are applicable to all fish species salvaged at the TFCF.

Biomass capacity (kg) of the TFCF fish-haul trucks was estimated based on the limiting water quality parameter (i.e., the water quality parameter that yielded the lowest biomass capacity estimate). Published fork length (FL; mm)-weight (g) relationships for Threadfin Shad (from Gartz 2004) were then used, along with the estimate of biomass capacity (kg) for the TFCF fish-haul trucks, to develop a curve estimating the carrying capacity (number of fish) that the fish-haul trucks can adequately transport based on fish size (from 20–150 mm FL). Estimated carrying capacities developed from this study were compared to carrying capacity estimates from the updated fish transport tables.

Selection of Water Quality Criteria

To determine fish-haul truck tank biomass capacity, it was necessary to select minimum (for O_2) or maximum (for TAN and CO_2) thresholds for each water quality parameter deemed important during fish transport. Since there is inherent stress associated with the salvage process at the TFCF, and stress may be compounding (Wendelaar Bonga 1997), water quality thresholds selected were generally non-lethal while still documented to affect fish health.

During development of biomass capacity estimates, minimum O_2 level for fish survival was considered to be 4.0 mg/L, which is the limit of DO below which fish health problems due to hypoxia begin for warmwater fish species (Wedemeyer 1996). The starting O_2 level in the truck was assumed to be 8.7 mg/L, which was the upper 95% confidence interval (CI) for DO measured at Grant Line Canal from January 1, 2018, through December 31, 2018 (California Data Exchange Center [CDEC] 2019).

The acute (1-hour average) TAN criteria for aquatic life provided by the Environmental Protection Agency (EPA 2013; 17.0 mg/L) was used as the maximum TAN level for fish survival during development of biomass capacity estimates based on TAN production. In addition, the starting TAN level in the fish-haul truck water was assumed to be 0.07 mg/L, which was the upper 95% CI for TAN measured in the Delta Mendota Canal from October 1, 2016, until September 30, 2018 (CDEC 2019).

When developing biomass capacity estimates based on CO_2 production, the maximum CO_2 concentration for fish survival was assumed to be 40.0 mg/L, which was the concentration described by Wedemeyer 1996 to cause respiratory distress and was considered the fish transport tolerance for warm and cool water fish. Since most surface waters contain 1–2 mg/L of CO_2 that has been dissolved from the atmosphere (produced by the microbial decomposition of organic matter in bottom sediment or by the respiration of microorganisms, algae, and other aquatic plants; Wedemeyer 1996), the starting CO_2 concentration in the fish-haul truck water was assumed to be 2.0 mg/L.

Results and Discussion

Water temperatures during sampling to investigate the rate of DO increase in a fish-haul truck tank while operating the compressed air system only, the O_2 system only, and both the air and O_2 systems simultaneously were 22.1–26.1 °C. Average water temperature during sampling was 24.3 °C.

Operation of only the O_2 system in the TFCF fish-haul trucks resulted in the greatest rate of DO increase (0.46 mg/L/min; Figure 3). Simultaneous operation of the compressed air and O_2 systems resulted in the next greatest rate of DO increase (0.32 mg/L/min), while operation of only the compressed air system resulted in the lowest rate of DO increase (0.05 mg/L/min; Figure 3). These results were as expected since pure O_2 produces a greater rate of O_2 increase over time than compressed air (approximately 21.0% O_2) and compressed air would be expected to dissipate excess O_2 during simultaneous operation of the two systems.

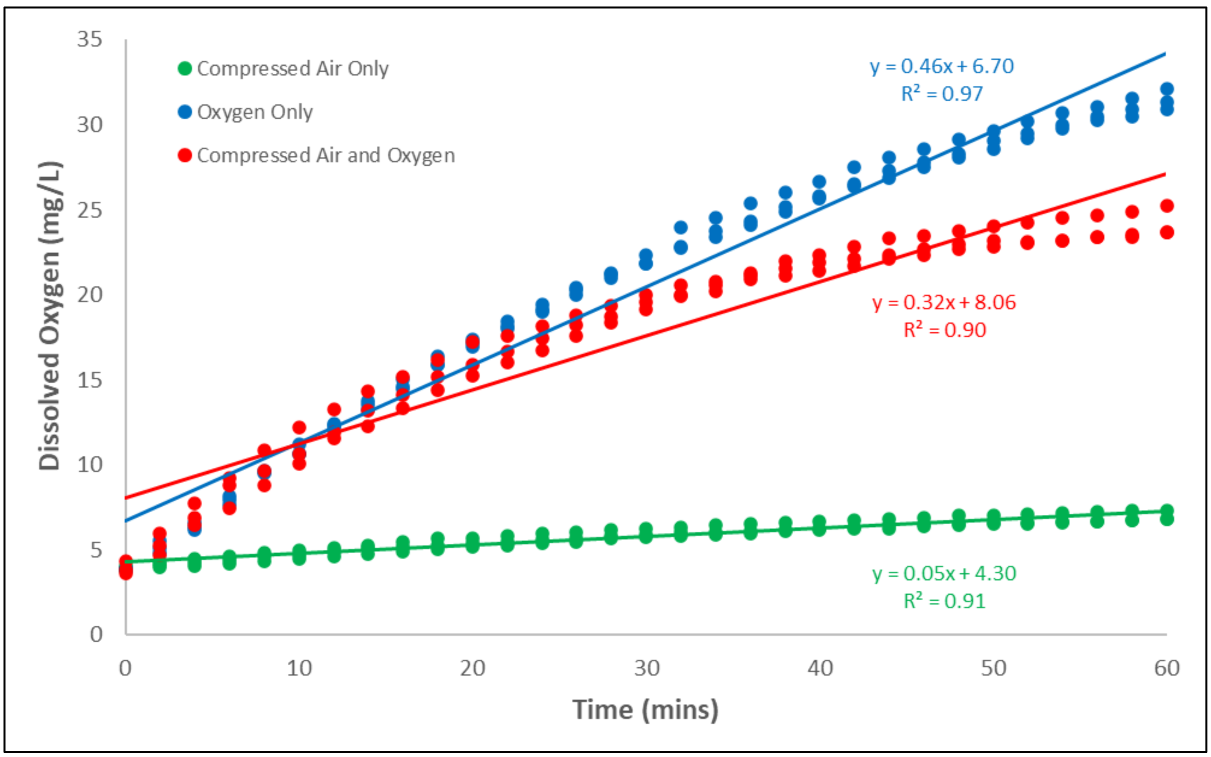

Figure 3.—Increase in dissolved oxygen (DO) in the Tracy Fish Collection Facility fish-haul trucks (9,914.0-L) over a 60-minute period when using only the compressed air system, only the oxygen (O_2) system, and simultaneous operation of both the compressed air and O_2 systems with water temperatures ≥ 22.0 °C and no fish in the truck tank. Linear trend lines were used to obtain a constant rate of DO increase for each system or combination of systems.

Using maximum estimates of fish O_2 consumption from Sutphin and Myrick (2015), biomass capacity of the TFCF fish-haul trucks was estimated to be 1,670.4 kg with only the O_2 system in operation, 1,236.6 kg with simultaneous operation of both the compressed air and O_2 systems, and 400.1 kg with only the compressed air system in operation (Table 1 and Appendix C [Table C-1]). These biomass capacity estimates assume a water volume of 9,914.0-L in the fish-haul truck tank and that O_2 and/or compressed air systems are operating at maximum sustainable capacity (approximately 8 L/min at 40 psi). The reduction in water volume with the addition of fish and/or debris in the truck tank, as well as operating the O_2 and/or compressed air systems at less than maximum sustainable capacity, would potentially affect biomass capacity estimates based on O_2 and compressed air system capabilities.

Using maximum estimates of fish TAN and CO_2 production from Sutphin and Hueth (2015), it was estimated that biomass capacity of the TFCF fish-haul trucks is 310.8 kg based on TAN production and 538.2 kg based on CO_2 production (Table 1 and Appendix C [Table C-2 and C-3]). Biomass capacity estimates based on TAN and CO_2 production assume a water volume of 9,914.0-L in the fish-haul truck tank and the addition of fish and/or debris in the truck tank would affect these estimates by reducing water volume. Results suggest biomass capacity of the fish-haul trucks is likely limited by TAN production and is approximately 310.8 kg, which is a fish loading density of 31.4 g/L. Since biomass capacity of the TFCF fish-haul trucks is likely limited by TAN production, it appears the O_2 and compressed air systems on the fish-haul trucks are adequate for the short-duration (approximately 1 h) transport of fish from the TFCF to release sites.

Table 1.—Biomass capacity of the Tracy Fish Collection Facility (TFCF) fish-haul trucks (9,914.0-L) with operation of the compressed air system only, oxygen (O_2) system only, and both the compressed air and O_2 systems simultaneously based on Threadfin Shad (*Dorosoma petenense)* O_2 consumption (0.19 mg O_2/g of fish/hour [Sutphin and Myrick 2015]), total ammonia nitrogen (TAN) production (0.54 mg TAN/g of fish/hour [Sutphin and Hueth 2015]), and carbon dioxide (CO_2) production (0.7 mg CO_2/g of fish/hour [Sutphin and Hueth 2015]) rates. It is assumed that biomass capacity estimates developed based on Threadfin Shad O_2 consumption, TAN production, and CO_2 production rates are applicable to all fish species salvaged at the TFCF.

System(s) in Operation	Biomass Capacity Based on Oxygen Consumption (0.19 mg/g/h; kg)	Biomass Capacity Based on Total Ammonia Nitrogen Production (0.54 mg/g/h; kg)	Biomass Capacity Based on Carbon Dioxide Production (0.70 mg/g/h; kg)
Compressed Air	400.1	310.8	538.2
Oxygen	1,670.4	310.8	538.2
Compressed Air and Oxygen	1,236.6	310.8	538.2

It is important to note that TAN is a measurement of the sum of nontoxic ammonium ions (NH_4^+) and toxic un-ionized ammonia (NH_3; Wedemeyer 1996). The proportion of these forms is a function of pH and temperature. High pH and, to a lesser degree, high temperature result in higher proportions of NH_3 (Murphy and Willis 1996). The pH of the water in the vicinity of the TFCF is typically between 7.1 and 8.3 (CDEC 2019). While these pH values are generally within the range considered to be desirable for both cold-and warmwater species in intensive culture (pH = 7–8 average; Wedemeyer 1996), there is still potential for ammonia toxicity issues, especially at higher water temperatures. However, in addition to ammonia, fish produce CO_2 during transport, which to some degree mitigates the toxicity of ammonia by reducing pH (Murphy and Willis 1996). Since this interaction was not considered during development of biomass capacity estimates based on TAN production, it is possible that the TAN-dependent biomass capacity estimate developed during this study may be biased low to some extent.

The loading density estimate obtained from this study for the TFCF fish-haul trucks (31.4 g/L) is below recommended guidelines for short-term (< 3 h) transport (50.0 g/L; Carmichael et al. 2001) and is less than the highest density of fish tested by Sutphin and Wu (2008; 64.5 g/L). This was expected since sampling was completed during times when the Delta water temperatures were ≥ 22.0 °C and maximum estimates of O_2 consumption, TAN production, and CO_2 production from Sutphin and Myrick (2015) and Sutphin and Hueth (2015) were used during this study to develop a conservative estimate of biomass capacity.

Carrying capacity (number of fish) for the TFCF fish-haul trucks was conservatively estimated using the TAN-limited biomass capacity estimate of 310.8 kg, as well as published length (mm)-weight (g) relationships for Threadfin Shad (Gartz 2004). By doing this, it was estimated that the fish-haul trucks can transport between 6,283 (150 mm fork length [FL]) and 3,486,100 (20 mm FL) fish over a 1 h period, depending on fish size (Figure 4 and Appendix D [Table D-1]).

Since the average water temperature while investigating the rate of DO increase in a fish-haul truck tank was 24.3 °C, a water temperature of 24.4 °C was used to estimate carrying capacity from the updated fish transport tables and make comparisons with carrying capacity estimates from this study. Estimated carrying capacities from this study for fish under 38.0 mm FL (506,395–3,486,100 fish, depending on fish size; Figure 4 and Appendix D [Table D-1]) were greater than the carrying capacity estimate calculated from the updated fish transport tables for fish under 38.1 mm FL (approximately 144,928 fish under 38.1 mm at 24.4 °C; Appendix B [Table B-1]). Carrying capacity estimates from this study for fish 38.0–63.0 mm FL (95,420–465,767 fish, depending on fish size; Figure 4 and Appendix D [Table D-1]) were less than the carrying capacity estimate calculated from the updated fish transport tables for fish 38.1–63.5 mm FL (approximately 113,636 fish at 24.4 °C) for certain sizes of fish within the range (i.e., fish 60.0–63.0 mm FL; Appendix B [Table B-2]). Carrying capacity estimates from this study for fish 64.0–114.0 mm FL (14,856–90,822 fish, depending on fish size; Figure 4 and Appendix D [Table D-1]) were greater than the carrying capacity estimate calculated from the updated fish transport tables for fish 63.5–114.3 mm FL (13,402 fish at 24.4 °C; Appendix B [Table B-3]). Carrying capacity estimates from this study for fish 115.0–150.0 mm FL (6,283–14,455 fish, depending on fish size; Figure 4 and Appendix D [Table D-1]) were less than the carrying capacity estimate calculated from the updated fish transport tables for fish over 114.3 mm FL (7,500 fish at 24.4 °C) for certain sizes of fish within the range (i.e., fish 142.0–150.0 mm FL; Appendix B [Table B-4]), although greater than carrying capacity estimates provided by updated fish transport tables for fish greater than 165.1 mm (approximately 3,846 fish at 24.4 °C; Appendix B [Table B-5]) and fish greater than 215.9 mm FL (approximately 2,597 fish at 24.4 °C; Appendix B [Table B-6]).

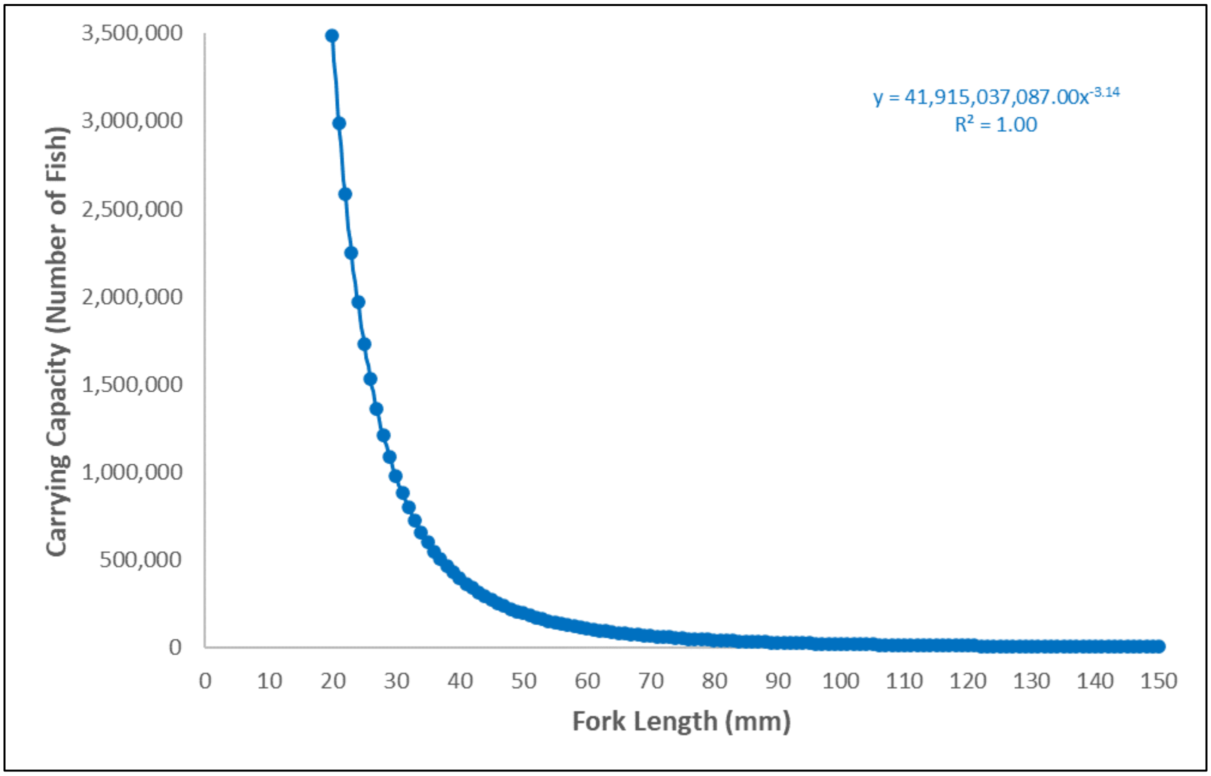

Figure 4.—Fork length (mm)-carrying capacity (number of fish) curve for the Tracy Fish Collection Facility fish-haul trucks (9,914.0-L) based on total ammonia nitrogen (TAN)-limited biomass capacity estimates and published length (mm)-weight (g) relationships for Threadfin Shad (*Dorosoma petenense*; Gartz 2004). The acute (1-hour average) TAN criteria for aquatic life provided by the Environmental Protection Agency (2013; 17.0 mg/L) was used as the maximum TAN level for fish survival.

There were disparities in carrying capacity estimates between this study and the updated fish transport tables for all sizes of fish. This was likely primarily due to the inclusion of TAN production and accumulation when developing carrying capacity estimates during this study. Variability in carrying capacity estimates may have also been due to differences in water temperature since Delta water temperatures were 22.1–26.1 °C while investigating the rate of DO increase in a fish-haul truck tank during this study, while a water temperature of 24.4 °C was used to determine carrying capacities according to updated fish transport tables. The use of maximum TAN production rates from Sutphin and Hueth (2015) during this study to develop biomass capacity and carrying capacity estimates, as well as the grouping of fish lengths into size classes by the updated fish transport tables, may have contributed to variability in carrying capacity estimates between this study and the updated fish transport tables. Differences in fish-haul truck tank volume may have also influenced carrying capacity estimates since the updated fish transport tables were developed for a 9,085.0-L fish-haul truck tank, while estimates from this study were developed using a 9,914.0-L fish-haul truck tank. In addition, the use of only older juvenile (Striped Bass and Chinook Salmon) and adult fish (Threadfin Shad and Delta Smelt) by Sutphin and Myrick (2015) and Sutphin and Hueth (2015) when developing O_2 consumption, TAN production, and CO_2 production rates may have affected carrying capacity estimates, especially for smaller fish that may have different metabolic rates per unit weight than the life stages investigated by Sutphin and Myrick (2015) and Sutphin and Hueth (2015; Kleiber 1947).

Ultimately, carrying capacity estimates from this study were lower than carrying capacity estimates from the updated fish transport tables for certain sizes of fish. This suggests TAN concentrations in the fish-haul truck tanks potentially exceed the acute TAN criteria for aquatic life provided by the Environmental Protection Agency (2013; 17.0 mg/L) when using the updated fish transport tables during fish transport operations at the TFCF.

Recommendations

To promote maintenance of adequate water quality parameters (i.e., DO ≥ 4.0 mg/L, TAN ≤ 17.0 mg/L, CO_2 ≤ 40.0 mg/L) in the fish-haul trucks used during salvage operations at the TFCF, it is recommended that the fish transport tables updated in 2010 for a 9,085.0-L fish-haul truck tank be further updated to include carrying capacity estimates developed during this study based on TAN production and accumulation in a 9,914.0-L fish-haul truck tank. Alternatively, potential methods to remove excessive TAN from water or reduce ammonia toxicity during fish transport should be researched and considered for implementation during the transport of fish from the TFCF to release sites (i.e., control of pH in the water contained in the fish-haul trucks to reduce the toxic form of ammonia, use of commercial water additives that detoxify or remove ammonia, use of live bacterial suspension, etc.). These approaches appear to be justified because the fish transport tables updated in 2010 that are currently used at the TFCF provide carrying capacity estimates that exceed estimates developed during this study for certain sizes of fish. Since results from this study suggest the O_2 and compressed air systems on the TFCF fish-haul trucks are adequate for short-duration (approximately 1 h) transport of fish, it is recommended that equivalent systems be incorporated on future fish-haul trucks designed for use at the TFCF.

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Appendix A—Fish Transport Tables (Developed by Bates et al., 1960, for a Fish-Haul Truck Tank Volume of 3,785.4 Liters)

Table A-1.—Fish transport table developed by Bates et al. (1960) for fish under 38.1 mm in length.

Table 10A.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures* Size Class A (Fish under 1.5 inches in length)																							
Water	**Thousands of Fish**																						
Temps.	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120
	(percent of load)																						
(°F.)																							
80	25	37	50	62	75	87	100																
79	22	33	44	55	66	77	88	100															
78	20	30	40	50	60	70	80	90	100														
77	18	27	36	45	54	63	72	81	90	100													
76	17	25	33	42	50	58	67	75	83	92	100												
75	15	23	31	38	46	54	62	69	77	85	92	100											
74	14	22	29	36	43	51	58	65	72	80	87	94	100										
73	14	21	27	34	41	48	55	62	68	75	82	89	96	100									
72	13	19	26	32	39	45	52	58	65	71	78	84	91	97	100								
71	12	19	25	31	37	43	49	56	62	68	74	80	86	93	99	100							
70	12	18	24	29	35	41	47	53	59	65	71	76	82	88	94	100							
69	11	17	22	28	34	39	45	51	56	62	67	73	79	84	90	96	100						
68	11	16	22	27	32	38	43	48	54	59	65	70	75	81	86	91	97	100					
67	10	15	21	26	31	36	41	46	52	57	62	67	72	77	82	88	93	98	100				
66	10	15	20	25	30	35	40	45	50	54	59	64	69	74	79	84	89	94	99				
65	10	14	19	24	29	33	38	43	48	52	57	62	67	71	76	81	86	90	95	100			
64	9	14	19	23	28	32	37	42	46	51	56	60	65	69	74	79	83	88	93	97	100		
63	9	14	18	23	27	32	36	41	45	50	54	59	63	68	72	77	81	86	90	95	100		
62	8	13	17	22	26	30	35	39	43	48	53	57	61	65	70	75	78	83	87	92	98		
61	8	12	17	21	26	29	34	38	42	47	51	55	59	64	68	73	77	81	85	89	94	100	
60	8	12	16	20	25	29	33	37	41	45	50	54	58	62	66	71	75	79	83	87	91	98	100

*** Determined from known numbers.**

Table A-2.—Fish transport table developed by Bates et al. (1960) for fish 38.1–63.5 mm in length.

Table 10B.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures
Size Class B (Fish between 1.5 and 2.5 inches in length)

Water	**Thousands of Fish**																
Temps.	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
								(percent of load)									
(°F.)																	
80	29	43	57	71	86	100											
79	26	39	53	65	79	92	100										
78	24	36	49	60	73	85	97	100									
77	23	35	47	58	69	81	93	100									
76	21	33	43	54	65	76	86	97	100								
75	20	31	40	51	61	71	82	91	100								
74	19	29	38	48	58	67	77	86	96								
73	18	27	36	45	54	63	72	81	90	100							
72	17	25	34	43	51	60	68	77	86	94							
71	16	24	32	40	48	56	64	72	80	88	96						
70	15	23	30	38	46	53	61	69	76	84	92	100					
69	14	22	29	36	44	51	58	66	73	80	88	95					
68	14	21	28	35	42	49	56	63	70	77	84	91	98				
67	13	20	27	34	41	47	54	61	68	75	82	89	95				
66	13	19	26	32	39	46	52	59	65	72	78	85	92	98			
65	12	18	25	31	37	44	50	56	63	69	75	82	88	94	100		
64	12	18	24	30	37	43	49	55	61	67	74	80	86	92	98		
63	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96		
62	11	17	23	29	34	40	46	52	58	63	69	75	81	87	93	99	
61	11	17	22	28	34	39	45	51	56	62	68	73	79	85	90	97	
60	11	16	22	27	33	38	44	50	55	61	66	72	77	83	88	93	100

Table A-3.—Fish transport table developed by Bates et al. (1960) for fish 63.5–114.3 mm in length.

Table 10C.--Percentage of a Truck Load Determined From Known Numbers of Fish in a Holding Tank
Size Class C (Fish between 2.5 and 4.5 Inches in Length)

Water Temps.	**Thousands of Fish** 1	2	3	4	5	6	7	8	9	10	11	12
	(percent of load)											
(°F.)												
80	25	50	75	100								
79	22	45	68	90								
78	20	41	62	83								
77	19	38	57	76	96							
76	17	35	53	71	89							
75	16	33	50	66	83	100						
74	15	31	46	62	78	93						
73	14	29	44	58	73	88						
72	13	27	41	55	69	83	97					
71	13	26	39	52	65	78	92					
70	12	25	37	50	62	75	87	100				
69	11	23	35	47	59	71	83	95				
68	11	22	34	45	56	68	79	90				
67	10	21	32	43	54	65	76	86	97			
66	10	20	31	42	52	62	72	83	93			
65	10	20	30	40	50	60	70	80	90	100		
64	9	19	28	38	48	57	67	76	86	96		
63	9	18	27	37	46	55	64	74	83	92		
62	8	17	26	35	44	53	62	71	80	89	98	
61	8	17	25	34	43	51	60	68	77	86	94	
60	8	16	25	33	41	50	58	66	75	83	91	100

Table A-4.—Fish transport table developed by Bates et al. (1960) for fish over 114.3 mm in length.

Table 10D.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures Size Class D (Fish over 4.5 inches in length)														
Water Temps.	**Thousands of Fish**													
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0
	(percent of load)													
(°F.)														
80	25	50	75	100										
79	21	43	65	86										
78	20	40	60	80	100									
77	17	35	53	71	89									
76	16	32	48	64	80	96								
75	15	30	45	60	75	90								
74	14	28	42	57	71	85	100							
73	13	26	39	52	65	78	92							
72	12	25	37	50	62	75	87	100						
71	11	23	34	46	58	69	81	93						
70	11	22	33	44	55	66	77	88	100					
69	10	20	31	41	52	62	72	83	93					
68	10	20	30	40	50	60	70	80	90	100				
67	9	18	28	37	47	56	66	75	84	94				
66	9	18	27	36	46	54	63	72	81	90	100			
65	8	17	26	34	43	51	60	68	77	86	94			
64	8	16	25	33	41	50	58	66	75	83	91	100		
63	7	15	23	31	39	47	55	63	71	79	87	95		
62	7	15	23	30	38	46	53	61	69	76	84	92	100	
61	7	14	22	29	36	44	52	58	66	73	80	88	95	
60	7	14	21	28	35	42	50	57	64	71	78	85	92	100

Table A-5.—Fish transport table developed by Bates et al. (1960) for Chinook Salmon (*Oncorhynchus tshawytscha*) 38.1–76.2 mm in length.

Table 10E.--Percentage of a Truck Load Determined From Known Numbers of Fish in a Holding Tank at Given Temperatures Size Class E (King Salmon Between 1.5 and 3.0 Inches in Length)												
Water	**Thousands of Fish**											
Temps.	5	10	15	20	25	30	35	40	45	50	55	60
	(percent of load)											
(°F.)												
70	13	27	41	55	69	83	97					
69	13	27	40	54	67	81	94					
68	12	25	38	51	64	76	89					
67	12	25	37	50	62	75	87	100				
66	11	23	35	47	59	71	83	95				
65	11	23	34	46	58	69	81	93				
64	11	22	34	45	56	68	79	90				
63	10	21	32	43	54	65	76	86	97			
62	10	21	31	42	53	63	74	85	95			
61	10	20	30	40	51	61	71	81	91			
60	10	20	30	40	50	60	70	80	90	100		
59	9	19	29	39	49	58	68	78	88	98		
58	9	19	28	38	48	57	67	76	86	96		
57	9	18	28	37	47	56	66	75	84	94		
56	9	18	27	37	46	55	64	74	83	92		
55	9	18	27	36	45	54	63	72	81	90	100	
54	8	17	26	35	44	53	62	71	80	89	98	
53	8	17	26	35	43	52	61	70	78	87	96	
52	8	17	25	34	43	51	60	68	77	86	94	
51	8	16	25	33	42	50	59	67	76	84	93	
50	8	16	25	33	41	50	58	66	75	83	91	100

Table A-6.—Fish transport table developed by Bates et al. (1960) for Chinook Salmon (*Oncorhynchus tshawytscha*) over 76.2 mm in length.

Table 10F.--Percentage of a Truck Load of Fish in a Holding Tank at Given Temperatures Size Class F (King Salmon over 3 inches in length)															
Water	**Thousands of Fish**														
Temps.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	(percent of load)														
(°F.)															
70	11	22	33	44	55	66	77	88	100						
69	10	21	32	43	53	64	75	86	96						
68	10	20	31	41	52	62	72	83	93						
67	10	20	30	40	50	60	70	80	90						
66	9	19	29	39	49	58	68	78	88	98					
65	9	19	28	38	47	57	66	76	85	95					
64	9	18	27	37	46	55	64	74	83	92					
63	9	18	27	36	45	54	63	72	81	90	99				
62	8	17	26	35	43	52	61	70	78	87	96				
61	8	17	25	34	42	51	59	68	76	85	94				
60	8	16	25	33	41	50	58	66	75	83	91	100			
59	8	16	24	32	40	48	56	65	73	81	89	97			
58	7	15	23	31	39	47	55	63	71	79	87	95			
57	7	15	23	31	38	46	54	62	69	77	85	93			
56	7	15	22	30	37	45	53	60	68	75	83	90	98		
55	7	14	22	29	37	44	51	59	66	74	81	88	96		
54	7	14	21	28	36	43	50	57	65	72	79	86	94		
53	7	14	21	28	35	42	49	56	63	70	78	85	92	99	
52	6	13	20	27	34	41	48	55	62	69	76	83	90	97	
51	6	13	20	27	34	40	47	54	61	68	74	81	88	95	
50	6	13	20	26	33	40	46	53	60	66	73	80	86	93	100

Appendix B—Fish Transport Tables (Updated in 2010 for a Fish-Haul Truck Tank Volume of 9,085.0 Liters)

Table B-1.—Updated fish transport table for fish under 38.1 mm in length.

2400 Gallon Tank: Percentage of truck load of fish in a holding tank at a given temperature Size Class A: Fish under 3.8 cm (1.5 inches) in length																																
Water	**Number of Fish**				**Thousands of Fish**																											
Temp.	100	250	500	750	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
(°F.)																																
80	0	0	0	1	1	2	3	4	5	6	7	8	9	10	16	21	26	31	36	42	47	52	57	62	68	73	78	83	88	94	99	104
79	0	0	0	1	1	2	3	4	5	5	6	7	8	9	14	18	23	28	32	37	41	46	51	55	60	64	69	74	78	83	87	92
78	0	0	0	1	1	2	3	3	4	5	6	7	8	8	13	17	21	25	29	33	38	42	46	50	54	58	63	67	71	75	79	83
77	0	0	0	0	1	1	2	3	4	4	5	6	7	7	11	15	19	23	26	30	34	38	41	45	49	53	56	60	64	68	72	75
76	0	0	0	1	1	1	2	3	3	4	5	6	6	7	10	14	17	21	24	28	31	35	38	42	45	49	52	56	59	62	66	69
75	0	0	0	0	1	1	2	3	3	4	4	5	6	6	10	13	16	19	22	26	29	32	35	38	42	45	48	51	55	58	61	64
74	0	0	0	0	1	1	2	2	3	4	4	5	5	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
73	0	0	0	1	1	1	2	2	3	4	4	5	5	6	9	11	14	17	20	23	26	28	31	34	37	40	42	45	48	51	54	57
72	0	0	0	1	1	1	2	2	3	3	4	4	5	5	8	11	13	16	19	21	24	27	29	32	35	38	40	43	46	48	51	54
71	0	0	1	1	1	1	2	2	3	3	4	4	5	5	8	10	13	15	18	21	23	26	28	31	33	36	38	41	43	46	48	51
70	0	0	0	0	1	1	2	2	3	3	3	4	4	5	7	10	12	15	17	20	22	24	27	29	32	34	37	39	42	44	46	49
69	0	0	0	0	0	1	1	2	2	3	3	4	4	5	7	9	12	14	16	19	21	23	26	28	30	33	35	37	40	42	44	47
68	0	0	0	0	1	1	1	2	2	3	3	4	4	5	7	9	11	13	16	18	20	22	25	27	29	31	33	36	38	40	42	45
67	0	0	0	0	1	1	1	2	2	3	3	4	4	4	6	9	11	13	15	17	19	21	24	26	28	30	32	34	36	38	41	43
66	0	0	0	0	1	1	1	2	2	3	3	3	4	4	6	8	10	12	14	17	19	21	23	25	27	29	31	33	35	37	39	41
65	0	0	0	0	0	1	1	2	2	2	3	3	4	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
64	0	0	0	0	0	1	1	2	2	2	3	3	4	4	6	8	10	12	14	15	17	19	21	23	25	27	29	31	33	35	37	38
63	0	0	0	0	0	1	1	2	2	2	3	3	3	4	6	8	9	11	13	15	17	19	21	23	24	26	28	30	32	34	36	38
62	0	0	0	0	0	1	1	1	2	2	2	3	3	3	5	7	9	11	13	14	16	18	20	22	24	26	27	29	31	33	35	37
61	0	0	0	0	0	0	1	1	2	2	2	3	3	3	5	7	9	11	12	14	16	18	19	21	23	25	27	28	30	32	34	36
60	0	0	0	0	0	0	1	1	2	2	2	3	3	3	5	7	8	10	12	14	15	17	19	21	22	24	26	28	29	31	33	35

Table B-2.—Updated fish transport table for fish 38.1–63.5 mm in length.

2400 Gallon Tank: Percentage of truck load of fish in a holding tank at a given temperature Size Class B: Fish between 3.8–6.4 cm (1.5–2.5 inches) in length																														
Water	**Number of Fish**				**Thousands of Fish**																									
Temp.	100	250	500	750	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40	45	50
(°F.)																														
80	0	0	1	1	1	2	4	5	6	7	8	10	11	12	13	14	16	17	18	19	20	21	23	24	30	36	42	48	54	59
79	0	1	1	1	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	27	32	38	43	48	54
78	1	1	1	1	2	3	4	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	34	39	44	49
77	0	1	1	1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	15	16	17	18	19	24	29	33	38	43	48
76	1	1	1	1	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	14	15	16	17	18	22	27	31	35	40	44
75	0	0	1	1	1	2	3	3	4	5	6	7	8	8	9	10	11	12	13	14	14	15	16	17	21	25	30	34	38	42
74	0	0	0	1	1	2	2	3	4	5	6	6	7	8	9	10	10	11	12	13	14	14	15	16	20	24	28	32	36	40
73	0	0	0	0	1	1	2	3	4	4	5	6	7	7	8	9	10	10	11	12	13	13	14	15	19	23	26	30	34	38
72	0	0	0	0	1	1	2	3	3	4	5	6	6	7	8	8	9	10	11	11	12	13	13	14	18	21	25	28	32	36
71	0	0	0	1	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10	11	11	12	13	13	17	20	23	27	30	33
70	0	0	0	0	1	1	2	2	3	4	4	5	6	6	7	8	8	9	9	10	11	11	12	13	16	19	22	25	29	32
69	0	0	0	0	0	1	2	2	3	4	4	5	5	6	7	7	8	8	9	10	10	11	11	12	15	18	21	24	27	30
68	0	0	0	0	1	1	2	2	3	4	4	5	5	6	6	7	8	8	9	9	10	11	11	12	15	18	20	23	26	29
67	0	0	0	0	0	1	2	2	3	3	4	4	5	6	6	7	7	8	8	9	10	10	11	11	14	17	20	23	25	28
66	0	0	0	0	0	1	2	2	3	3	4	4	5	5	6	6	7	8	8	9	9	10	10	11	14	16	19	22	24	27
65	0	0	0	0	0	1	1	2	2	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	13	16	18	21	23	26
64	0	0	0	0	0	1	1	2	2	3	3	4	4	5	6	6	7	7	8	8	9	9	10	10	13	15	18	20	23	26
63	0	0	0	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	13	15	18	20	23	25
62	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	12	14	17	19	22	24
61	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	12	14	16	19	21	24
60	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8	9	9	11	14	16	18	21	23

Table B-3.—Updated fish transport table for fish 63.5–114.3 mm in length.

2400 Gallon Tank: Percentage of truck load of fish in a holding tank at a given temperature
Size Class C: Fish between 6.4–11.4 cm (2.5–4.5 inches) in length

Water	**Number of Fish**				**Thousands of Fish**																					
Temp.	100	250	500	750	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30
(°F.)																										
80	1	3	5	8	10	21	31	42	52	63	73	83	94	104	115	125	135	146	156	167	177	188	198	208	260	313
79	1	2	5	7	9	19	28	38	47	56	66	75	85	94	104	113	122	132	141	151	160	169	179	188	235	282
78	1	2	4	6	9	17	26	35	43	52	61	69	78	87	95	104	113	121	130	139	147	156	165	173	217	260
77	1	2	4	6	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	143	151	159	199	239
76	1	2	4	5	7	15	22	30	37	44	52	59	67	74	82	89	97	104	111	119	126	134	141	149	186	223
75	1	2	3	5	7	14	21	28	35	42	49	55	62	69	76	83	90	97	104	111	118	125	132	139	174	208
74	1	2	3	5	6	13	19	26	32	39	45	52	58	65	71	78	84	91	97	104	110	117	123	130	162	195
73	0	1	3	4	6	12	18	24	30	37	43	49	55	61	67	73	79	85	92	98	104	110	116	122	153	183
72	0	1	3	4	6	11	17	23	29	35	40	46	52	58	64	69	75	81	87	93	98	104	110	116	145	174
71	0	1	3	4	5	11	16	22	27	33	38	44	49	54	60	65	71	76	82	87	93	98	104	109	136	163
70	0	1	3	4	5	10	16	21	26	31	36	42	47	52	57	62	68	73	78	83	88	94	99	104	130	156
69	0	1	2	3	5	10	15	20	25	30	35	40	44	49	54	59	64	69	74	79	84	89	94	99	124	149
68	0	1	2	3	5	9	14	19	23	28	33	38	42	47	52	56	61	66	71	75	80	85	89	94	118	141
67	0	1	2	3	4	9	13	18	22	27	31	36	41	45	50	54	59	63	68	72	77	81	86	90	113	135
66	0	1	2	3	4	9	13	17	22	26	30	34	39	43	47	52	56	60	65	69	73	78	82	86	108	130
65	0	1	2	3	4	8	13	17	21	25	29	33	38	42	46	50	54	58	63	67	71	75	79	83	104	125
64	0	1	2	3	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	100	120
63	0	1	2	3	4	8	11	15	19	23	27	31	35	38	42	46	50	54	58	61	65	69	73	77	96	115
62	0	1	2	3	3	7	11	15	18	22	26	30	33	37	41	45	48	52	56	59	63	67	71	74	93	112
61	0	1	2	3	3	7	11	14	18	21	25	28	32	36	39	43	46	50	54	57	61	64	68	71	89	107
60	0	1	2	2	3	7	10	14	17	21	24	28	31	35	38	42	45	48	52	55	59	62	66	69	87	104

Table B-4.—Updated fish transport table for fish over 114.3 mm in length.

2400 Gallon Truck: Percentage of truck load of fish in a holding tank at a given temperature Size Class D: Fish over 11 cm (4.5 inches) in length																							
Water	**Number of Fish**				**Thousands of Fish**																		
Temp.	100	250	500	750	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
(°F.)																							
80	2	5	10	16	21	31	42	52	63	73	83	94	104	115	125	135	146	156	167	177	188	198	208
79	2	4	9	13	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180
78	2	4	8	13	17	25	33	42	50	58	67	75	83	92	100	108	117	125	133	142	150	158	167
77	1	4	7	11	15	22	30	37	44	52	59	67	74	82	89	97	104	111	119	126	134	141	149
76	1	3	7	10	13	20	27	33	40	47	53	60	67	73	80	87	93	100	107	113	120	127	133
75	1	3	6	9	13	19	25	31	38	44	50	56	63	69	75	81	88	94	100	106	113	119	125
74	1	3	6	9	12	18	24	30	36	41	47	53	59	65	71	77	83	89	95	101	107	113	119
73	1	3	5	8	11	16	22	27	33	38	44	49	54	60	65	71	76	82	87	93	98	104	109
72	1	3	5	8	10	16	21	26	31	36	42	47	52	57	62	68	73	78	83	88	94	99	104
71	1	2	5	7	10	14	19	24	29	34	39	43	48	53	58	63	68	73	77	82	87	92	97
70	1	2	5	7	9	14	18	23	28	32	37	41	46	51	55	60	64	69	74	78	83	87	92
69	1	2	4	6	9	13	17	21	26	30	34	39	43	47	52	56	60	65	69	73	78	82	86
68	1	2	4	6	8	13	17	21	25	29	33	38	42	46	50	54	58	63	67	71	75	79	83
67	1	2	4	6	8	12	16	19	23	27	31	35	39	43	47	51	55	59	63	67	70	74	78
66	1	2	4	6	7	11	15	19	23	26	30	34	38	41	45	49	53	57	60	64	68	72	75
65	1	2	4	5	7	11	14	18	21	25	29	32	36	39	43	46	50	54	57	61	64	68	71
64	1	2	3	5	7	10	14	17	21	24	28	31	35	38	42	45	48	52	55	59	62	66	69
63	0	1	3	5	6	10	13	16	20	23	26	30	33	36	40	43	46	49	53	56	59	63	66
62	0	1	3	5	6	9	13	16	19	22	25	29	32	35	38	41	45	48	51	54	57	61	64
61	1	1	3	4	6	9	12	15	18	21	24	27	30	34	37	40	43	46	49	52	55	58	61
60	0	1	3	4	6	9	12	15	18	21	24	27	30	33	36	38	41	44	47	50	53	56	59

Table B-5.—Updated fish transport table for fish over 165.1 mm in length.

2400 Gallon Tank: Percentage of truck load of fish in a holding tank at a given temperature Size Class G: Fish greater than 16.3 cm (6.5 inches) in length																										
Water	**Number of Fish**				**Thousands of Fish**																					
Temp.	100	250	500	750	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30
(°F.)																										
80	4	10	20	30	40	81	121	161	201	242	282	322	363	403	443	483	524	564	604	644	685	725	765	806	1007	1208
79	3	9	17	26	35	70	105	140	174	209	244	279	314	349	384	419	454	489	523	558	593	628	663	698	872	1047
78	3	8	16	24	32	65	97	129	162	194	226	259	291	323	355	388	420	452	485	517	549	582	614	646	808	970
77	3	7	14	22	29	58	87	115	144	173	202	231	260	288	317	346	375	404	433	461	490	519	548	577	721	865
76	3	6	13	19	26	52	78	104	130	155	181	207	233	259	285	311	337	363	389	415	441	466	492	518	648	777
75	2	6	12	18	24	49	73	97	121	146	170	194	218	243	267	291	315	340	364	388	412	437	461	485	606	728
74	2	6	12	17	23	46	69	92	115	138	161	184	207	230	253	276	299	323	346	369	392	415	438	461	576	691
73	2	5	11	16	21	42	63	85	106	127	148	169	190	212	233	254	275	296	317	338	360	381	402	423	529	635
72	2	5	10	15	20	40	61	81	101	121	141	162	182	202	222	242	263	283	303	323	343	364	384	404	505	606
71	2	5	9	14	19	38	56	75	94	113	132	151	169	188	207	226	245	263	282	301	320	339	357	376	470	564
70	2	4	9	13	18	36	54	72	89	107	125	143	161	179	197	215	232	250	268	286	304	322	340	358	447	536
69	2	4	8	13	17	34	50	67	84	101	118	134	151	168	185	202	218	235	252	269	285	302	319	336	420	504
68	2	4	8	12	16	32	49	65	81	97	113	129	146	162	178	194	210	226	243	259	275	291	307	323	404	485
67	2	4	8	11	15	30	46	61	76	91	107	122	137	152	168	183	198	213	229	244	259	274	289	305	381	457
66	1	4	7	11	15	29	44	59	73	88	103	117	132	147	161	176	191	205	220	234	249	264	278	293	366	440
65	1	3	7	10	14	28	42	56	69	83	97	111	125	139	153	167	180	194	208	222	236	250	264	278	347	416
64	1	3	7	10	13	27	40	54	67	81	94	108	121	135	148	162	175	188	202	215	229	242	256	269	337	404
63	1	3	6	10	13	26	39	51	64	77	90	103	116	129	142	154	167	180	193	206	219	232	244	257	322	386
62	1	3	6	9	12	25	37	50	62	75	87	99	112	124	137	149	162	174	186	199	211	224	236	249	311	373
61	1	3	6	9	12	24	36	47	59	71	83	95	107	118	130	142	154	166	178	189	201	213	225	237	296	355
60	1	3	6	9	12	23	35	46	58	69	81	92	104	115	127	138	150	161	173	184	196	207	219	230	288	345

Table B-6.—Updated fish transport table for fish over 215.9 mm in length.

2400 Gallon Tank: Percentage of truck load of fish in a holding tank at a given temperature
Size Class H: Fish greater than 21.3 cm (8.5 inches) in length

Water	Number of Fish				Thousands of Fish																					
Temp.	100	250	500	750	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30
(°F.)																										
80	6	15	30	45	60	120	180	240	300	360	419	479	539	599	659	719	779	839	899	959	1019	1079	1139	1199	1498	1798
79	5	13	26	39	52	104	155	207	259	311	363	415	466	518	570	622	674	726	777	829	881	933	985	1037	1296	1555
78	5	12	24	36	48	96	144	192	240	288	336	384	432	480	528	576	624	672	720	768	816	864	912	960	1200	1441
77	4	11	21	32	43	86	128	171	214	257	299	342	385	428	470	513	556	599	642	684	727	770	813	855	1069	1283
76	4	10	19	29	38	77	115	154	192	230	269	307	345	384	422	461	499	537	576	614	652	691	729	768	960	1151
75	4	9	18	27	36	72	108	144	180	215	251	287	323	359	395	431	467	503	539	575	610	646	682	718	898	1077
74	3	9	17	26	34	68	102	137	171	205	239	273	307	341	375	410	444	478	512	546	580	614	649	683	853	1024
73	3	8	16	23	31	63	94	125	157	188	219	250	282	313	344	376	407	438	470	501	532	563	595	626	783	939
72	3	7	15	22	30	60	90	120	149	179	209	239	269	299	329	359	389	419	448	478	508	538	568	598	747	897
71	3	7	14	21	28	56	84	111	139	167	195	223	251	278	306	334	362	390	418	445	473	501	529	557	696	835
70	3	7	13	20	26	53	79	106	132	159	185	212	238	264	291	317	344	370	397	423	450	476	502	529	661	793
69	2	6	12	19	25	50	74	99	124	149	174	199	223	248	273	298	323	348	372	397	422	447	472	497	621	745
68	2	6	12	18	24	48	72	96	120	144	167	191	215	239	263	287	311	335	359	383	407	431	454	478	598	718
67	2	6	11	17	23	45	68	90	113	135	158	180	203	225	248	270	293	315	338	360	383	405	428	450	563	675
66	2	5	11	16	22	43	65	87	108	130	152	173	195	217	238	260	282	303	325	347	368	390	412	433	542	650
65	2	5	10	15	20	41	61	82	102	123	143	164	184	205	225	246	266	287	307	328	348	369	389	410	512	615
64	2	5	10	15	20	40	60	80	99	119	139	159	179	199	219	239	259	278	298	318	338	358	378	398	497	597
63	2	5	10	14	19	38	57	76	95	114	133	152	171	190	209	228	247	266	285	304	323	342	361	380	475	570
62	2	5	9	14	18	37	55	73	92	110	128	147	165	184	202	220	239	257	275	294	312	330	349	367	459	551
61	2	4	9	13	17	35	52	70	87	105	122	140	157	175	192	210	227	245	262	280	297	315	332	350	437	524
60	2	4	8	13	17	34	51	68	85	102	119	136	153	170	187	204	221	238	255	272	289	306	323	340	424	509

Appendix C—Calculation of Biomass Capacity Estimates for the Current (Fourth-Generation) Tracy Fish Collection Facility Fish-Haul Trucks

Table C-1.—Calculation of biomass capacity estimates for the Tracy Fish Collection Facility fish-haul trucks (9,914.0-L) with operation of the compressed air system only, oxygen (O_2) system only, and both the compressed air and O_2 systems simultaneously based on maximum Threadfin Shad (*Dorosoma petenense*) O_2 consumption rate (0.19 mg O_2/g of fish/hour; Sutphin and Myrick 2015).

Category	Value	Source/Reference
Oxygen Consumption Rate (mg/g/h)	0.19	Maximum oxygen consumption rate for Threadfin Shad (*Dorosoma petenense*) from Sutphin and Myrick (2015). Threadfin Shad exhibited the highest oxygen consumption rate of all species tested.
Oxygen Consumption Rate (mg/g/min)	0.0032	Converted from 0.19 mg/g/h.
Oxygen Level in Truck at Start (mg/L)	8.7	Upper 95% confidence interval for dissolved oxygen measured at Grant Line Canal from January 1, 2018, through December 31, 2018 (California Data Exchange Center).
Minimum Oxygen Level for Survival (mg/L)	4.0	The limit of dissolved oxygen below which fish health problems due to hypoxia begin for warmwater fish species according to Wedemeyer (1996).
Concentration of Oxygen That Can Be Consumed Without Input (mg/L)	4.7	Calculated by subtracting Minimum Oxygen Level for Survival (mg/L) from Oxygen Level in Truck at Start (mg/L).
Volume of Fish-Haul Truck (L)	9,914.0	From Reclamation (2007) and Reyes et al. (2018).
Amount of Oxygen That Can Be Consumed in Truck Without Input (mg)	46,595.8	Calculated by multiplying Concentration of Oxygen That Can Be Consumed Without Input (mg/L) by Volume of Fish-Haul Truck (L).
Oxygen Production Rate - Compressed Air (mg/L/min)	0.05	From this study.
Oxygen Production Rate - Compressed Air (mg/min)	495.7	Calculated by multiplying Oxygen Production Rate - Compressed Air (mg/L/min) by Volume of Fish-Haul Truck (L).
Oxygen Production Rate - Oxygen (mg/L/min)	0.46	From this study.
Oxygen Production Rate - Oxygen (mg/min)	4,560.4	Calculated by multiplying Oxygen Production Rate - Oxygen (mg/L/min) by Volume of Fish-Haul Truck (L).

Category	Value	Source/Reference
Oxygen Production Rate - Compressed Air and Oxygen (mg/L/min)	0.32	From this study.
Oxygen Production Rate - Compressed Air and Oxygen (mg/min)	3,172.5	Calculated by multiplying Oxygen Production Rate - Compressed Air and Oxygen (mg/L/min) by Volume of Fish-Haul Truck (L).
Truck Biomass Capacity Without Oxygen Input (g)	245,241.1	Calculated by dividing Amount of Oxygen That Can Be Consumed in Truck Without Input (mg) by Oxygen Consumption Rate (mg/g/h).
Compressed Air Biomass Capacity (g)	154,906.3	Calculated by dividing Oxygen Production Rate - Compressed Air (mg/min) by Oxygen Consumption Rate (mg/g/min).
Oxygen Biomass Capacity (g)	1,425,125.0	Calculated by dividing Oxygen Production Rate - Oxygen (mg/min) by Oxygen Consumption Rate (mg/g/min).
Compressed Air and Oxygen Biomass Capacity (g)	991,406.3	Calculated by dividing Oxygen Production Rate - Compressed Air and Oxygen (mg/min) by Oxygen Consumption Rate (mg/g/min).
Total Biomass Capacity - Compressed Air (g)	400,147.4	Calculated by summing Truck Biomass Capacity Without Oxygen Input (g) and Compressed Air Biomass Capacity (g).
Total Biomass Capacity - Compressed Air (kg)	**400.1**	**Converted from 400,147.4 g.**
Total Biomass Capacity - Oxygen (g)	1,670,366.1	Calculated by summing Truck Biomass Capacity Without Oxygen Input (g) and Oxygen Biomass Capacity (g).
Total Biomass Capacity - Oxygen (kg)	**1,670.4**	**Converted from 1,670,366.1 g.**
Total Biomass Capacity - Compressed Air and Oxygen (g)	1,236,647.4	Calculated by summing Truck Biomass Capacity Without Oxygen Input (g) and Compressed Air and Oxygen Biomass Capacity (g).
Total Biomass Capacity - Compressed Air and Oxygen (kg)	**1,236.6**	**Converted from 1,236,647.4 g.**

Table C-2.—Calculation of biomass capacity estimate for the Tracy Fish Collection Facility (TFCF) fish-haul trucks (9,914.0-L) based on maximum Threadfin Shad (*Dorosoma petenense*) total ammonia nitrogen (TAN) production rate (0.54 mg TAN/g of fish/hour; Sutphin and Hueth 2015).

Category	Value	Source/Reference
Total Ammonia Nitrogen Production Rate (mg/g/h)	0.54	Maximum total ammonia nitrogen production rate for Threadfin Shad (*Dorosoma petenense*) from Sutphin and Hueth (2015). Threadfin Shad exhibited the highest total ammonia nitrogen production rate of all species tested.
Total Ammonia Nitrogen Level in Truck at Start (mg/L)	0.07	Upper 95% confidence interval for total ammonia nitrogen measured in the Delta-Mendota Canal from October 1, 2016, through September 30, 2018 (California Data Exchange Center).

Category	Value	Source/Reference
Maximum Total Ammonia Nitrogen Level for Survival (mg/L)	17.0	Acute (1-hour average) total ammonia nitrogen criteria for aquatic life according to EPA (2013).
Concentration of Total Ammonia Nitrogen That Can Be Produced (mg/L)	16.93	Calculated by subtracting Total Ammonia Level in Truck at Start (mg/L) from Maximum Total Ammonia Level for Survival (mg/L).
Volume of Fish-Haul Truck (L)	9,914.0	From Reclamation (2007) and Reyes et al. (2018).
Amount of Total Ammonia Nitrogen That Can Be Produced in Truck (mg)	167,844.0	Calculated by multiplying Concentration of Total Ammonia Nitrogen That Can Be Produced (mg/L) by Volume of Fish-Haul Truck (L).
Truck Biomass Capacity (g)	310,822.2	Calculated by dividing Amount of Total Ammonia Nitrogen That Can Be Produced in Truck (mg) by Total Ammonia Nitrogen Production Rate (mg/g/h).
Truck Biomass Capacity (kg)	**310.8**	**Converted from 310,822.2 g.**

Table C-3.—Calculation of biomass capacity estimate for the Tracy Fish Collection Facility (TFCF) fish-haul trucks (9,914.0-L) based on maximum Threadfin Shad (*Dorosoma petenense*) carbon dioxide (CO_2) production rate (0.7 mg CO_2/g of fish/hour; Sutphin and Hueth 2015).

Category	Value	Source/Reference
Total Carbon Dioxide Production Rate (mg/g/h)	0.7	Maximum carbon dioxide production rate for Threadfin Shad (*Dorosoma petenense*) from Sutphin and Hueth (2015). Threadfin Shad exhibited the highest carbon dioxide production rate of all species tested.
Total Carbon Dioxide Level in Truck at Start (mg/L)	2.0	Based on statement by Wedemeyer (1996) that most surface waters contain 1-2 mg/L carbon dioxide.
Maximum Carbon Dioxide Level for Survival (mg/L)	40.0	Carbon dioxide concentration that was described by Wedemeyer (1996) to cause respiratory distress and considered to be the fish transport tolerance for warm and cool water fish.
Concentration of Carbon Dioxide That Can Be Produced (mg/L)	38.0	Calculated by subtracting Total Carbon Dioxide Level in Truck at Start (mg/L) from Maximum Carbon Dioxide Level for Survival (mg/L).
Volume of Fish-Haul Truck (L)	9,914.0	From Reclamation (2007) and Reyes et al. (2018).
Amount of Carbon Dioxide That Can Be Produced in Truck (mg)	376,732.0	Calculated by multiplying Concentration of Carbon Dioxide That Can Be Produced (mg/L) by Volume of Fish-Haul Truck (L)
Truck Biomass Capacity (g)	538,188.6	Calculated by dividing Amount of Carbon Dioxide That Can Be Produced in Truck (mg) by Total Carbon Dioxide Production Rate (mg/g/h).
Truck Biomass Capacity (kg)	**538.2**	**Converted from 538,188.6 g.**

Appendix D—Estimated Carrying Capacity (Number of Fish) of the Current (Fourth-Generation) Tracy Fish Collection Facility Fish-Haul Trucks

Table D-1.—Estimated Carrying Capacity (Number of Fish) of the Current (Fourth-Generation) Tracy Fish Collection Facility Fish-Haul Trucks for 20–150 mm Fish based on Total Ammonia Nitrogen-Limited Biomass Capacity Estimate and Published Length (mm)-Weight (g) Relationship for Threadfin Shad (*Dorosoma petenense*) from Gartz (2004).

Fork Length (mm)	Weight (g)	Biomass Capacity (kg)	Biomass Capacity (g)	Carrying Capacity (number of fish)
20	0.09	310.8	310,800	3,486,100
21	0.10	310.8	310,800	2,991,508
22	0.12	310.8	310,800	2,585,427
23	0.14	310.8	310,800	2,249,010
24	0.16	310.8	310,800	1,968,010
25	0.18	310.8	310,800	1,731,530
26	0.20	310.8	310,800	1,531,135
27	0.23	310.8	310,800	1,360,232
28	0.26	310.8	310,800	1,213,619
29	0.29	310.8	310,800	1,087,151
30	0.32	310.8	310,800	977,502
31	0.35	310.8	310,800	881,982
32	0.39	310.8	310,800	798,398
33	0.43	310.8	310,800	724,953
34	0.47	310.8	310,800	660,164
35	0.52	310.8	310,800	602,799
36	0.56	310.8	310,800	551,830
37	0.61	310.8	310,800	506,395
38	0.67	310.8	310,800	465,767
39	0.72	310.8	310,800	429,330
40	0.78	310.8	310,800	396,561
41	0.85	310.8	310,800	367,012
42	0.91	310.8	310,800	340,299
43	0.98	310.8	310,800	316,091
44	1.06	310.8	310,800	294,105
45	1.13	310.8	310,800	274,091
46	1.21	310.8	310,800	255,836
47	1.30	310.8	310,800	239,150
48	1.39	310.8	310,800	223,871

Fork Length (mm)	Weight (g)	Biomass Capacity (kg)	Biomass Capacity (g)	Carrying Capacity (number of fish)
49	1.48	310.8	310,800	209,853
50	1.58	310.8	310,800	196,970
51	1.68	310.8	310,800	185,110
52	1.78	310.8	310,800	174,174
53	1.89	310.8	310,800	164,074
54	2.01	310.8	310,800	154,733
55	2.13	310.8	310,800	146,081
56	2.25	310.8	310,800	138,055
57	2.38	310.8	310,800	130,601
58	2.51	310.8	310,800	123,669
59	2.65	310.8	310,800	117,214
60	2.80	310.8	310,800	111,196
61	2.94	310.8	310,800	105,579
62	3.10	310.8	310,800	100,330
63	3.26	310.8	310,800	95,420
64	3.42	310.8	310,800	90,822
65	3.59	310.8	310,800	86,511
66	3.77	310.8	310,800	82,467
67	3.95	310.8	310,800	78,668
68	4.14	310.8	310,800	75,097
69	4.33	310.8	310,800	71,736
70	4.53	310.8	310,800	68,571
71	4.74	310.8	310,800	65,588
72	4.95	310.8	310,800	62,773
73	5.17	310.8	310,800	60,116
74	5.40	310.8	310,800	57,605
75	5.63	310.8	310,800	55,230
76	5.87	310.8	310,800	52,983
77	6.11	310.8	310,800	50,855
78	6.36	310.8	310,800	48,838
79	6.62	310.8	310,800	46,926
80	6.89	310.8	310,800	45,111
81	7.16	310.8	310,800	43,387
82	7.44	310.8	310,800	41,749
83	7.73	310.8	310,800	40,192
84	8.03	310.8	310,800	38,711
85	8.33	310.8	310,800	37,300
86	8.64	310.8	310,800	35,957
87	8.96	310.8	310,800	34,677
88	9.29	310.8	310,800	33,456
89	9.62	310.8	310,800	32,291
90	9.97	310.8	310,800	31,179
91	10.32	310.8	310,800	30,117
92	10.68	310.8	310,800	29,103

Fork Length (mm)	Weight (g)	Biomass Capacity (kg)	Biomass Capacity (g)	Carrying Capacity (number of fish)
93	11.05	310.8	310,800	28,132
94	11.42	310.8	310,800	27,205
95	11.81	310.8	310,800	26,317
96	12.20	310.8	310,800	25,466
97	12.61	310.8	310,800	24,652
98	13.02	310.8	310,800	23,872
99	13.44	310.8	310,800	23,124
100	13.87	310.8	310,800	22,406
101	14.31	310.8	310,800	21,718
102	14.76	310.8	310,800	21,057
103	15.22	310.8	310,800	20,423
104	15.69	310.8	310,800	19,813
105	16.16	310.8	310,800	19,227
106	16.65	310.8	310,800	18,664
107	17.15	310.8	310,800	18,123
108	17.66	310.8	310,800	17,602
109	18.18	310.8	310,800	17,100
110	18.70	310.8	310,800	16,617
111	19.24	310.8	310,800	16,152
112	19.79	310.8	310,800	15,704
113	20.35	310.8	310,800	15,273
114	20.92	310.8	310,800	14,856
115	21.50	310.8	310,800	14,455
116	22.09	310.8	310,800	14,068
117	22.70	310.8	310,800	13,694
118	23.31	310.8	310,800	13,334
119	23.93	310.8	310,800	12,985
120	24.57	310.8	310,800	12649
121	25.22	310.8	310,800	12,324
122	25.88	310.8	310,800	12,010
123	26.55	310.8	310,800	11,707
124	27.23	310.8	310,800	11,413
125	27.93	310.8	310,800	11,129
126	28.63	310.8	310,800	10,854
127	29.35	310.8	310,800	10,589
128	30.08	310.8	310,800	10331
129	30.83	310.8	310,800	10,082
130	31.58	310.8	310,800	9,841
131	32.35	310.8	310,800	9,607
132	33.13	310.8	310,800	9,381
133	33.92	310.8	310,800	9,162
134	34.73	310.8	310,800	8,949
135	35.55	310.8	310,800	8,743
136	36.38	310.8	310,800	8,543

Fork Length (mm)	Weight (g)	Biomass Capacity (kg)	Biomass Capacity (g)	Carrying Capacity (number of fish)
137	37.23	310.8	310,800	8,349
138	38.09	310.8	310,800	8,160
139	38.96	310.8	310,800	7,978
140	39.84	310.8	310,800	7,800
141	40.74	310.8	310,800	7,628
142	41.66	310.8	310,800	7,461
143	42.58	310.8	310,800	7,299
144	43.52	310.8	310,800	7,141
145	44.48	310.8	310,800	6,987
146	45.45	310.8	310,800	6,838
147	46.43	310.8	310,800	6,694
148	47.43	310.8	310,800	6,553
149	48.44	310.8	310,800	6,416
150	49.47	310.8	310,800	6,283