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A SUMMARY REVIEW OF THE CURRENT LITERATURE CONCERNING TRANSPORTATION OF FISH

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Seattle, Washington

February 1, 1963

Types of injury. These may be classified as mechanical and physiological, the latter being further divided into the effects of anoxia, and of toxic materials. Mechanical injuries, whether caused by motion of the container, the water, or the fish, are generally contusions and abrasions caused by contact with the walls. Anoxia may be caused by an inadequate oxygen supply, or by mechanical obstruction of the gills by mucus, detritus, feces, or regurgitated food. Anoxia can also be caused by warming of the water, or excessive activity of the fish. These frequently go together, and interact to worsen the situation [14]. Toxic effects may be caused by carbon dioxide, ammonia and other products of metabolism; substances produced by bacterial action upon metabolic products, feces, and detrital material (slime, abraded scales, etc); and by metallic ions or other material present in the water or dissolved from the container.

The following discussion is primarily concerned with tank transport of fish, and only incidentally with other means.

Mechanical injuries can be reduced by appropriate design. Large tanks are usually baffled or otherwise designed to prevent sloshing [25; 42]. In some cases a jet of water is used to maintain a circulation; active species may thus be induced to orient themselves to maintain position in the water [23; 42; 99].

Bait boats often have a light over the tanks to promote "balling" of the fish [63, p. 9]. The application of these techniques to the transport of salmonids seems doubtful, especially where cold or drugs are used to reduce activity. Groves (personal communication) used 1/4 inch neoprene foam liner for a tank to haul adult salmon at the Montlake Behavior Laboratory, Bureau of Commercial Fisheries, Seattle. The necessity of maintaining low temperatures for the transportation of salmonids is well-known. Suitable insulation [3; 63, p. 8] will often eliminate or reduce need for refrigeration on short hauls, and is essential to efficient operation of refrigerated tanks and to conservation of ice. The effect of cold is to reduce activity directly, to lower the metabolic rate, and assist in conservation of dissolved oxygen.

It is usually necessary to replenish the oxygen supply, either by air or pure oxygen. Several methods are available. Spray aeration is very common [25; 63, p. 12; 65] but may be inefficient in promoting proper circulation. The action of baffles and screen depends upon movement of the water to break it up and expose it to the air. A screen may be used to further break up a spray jet [104]. Venturi aeration systems are used on large fish transport tanks [25; 42; 63, p. 13]. Spray and Venturi methods of aeration may cause excessive foaming, [96] which may be increased by slime from the fish and by

some narcotics [93]. Organic anti-foam compounds have been used to counteract this [52; 93]. Compressed gas liberation is perhaps the most widely used technique. [64, p. 13; 25; 37; 71]. The gas is usually pure oxygen, diffused through a porous block or a perforated pipe. An unusual combination of this principle with the air lift pump is described in reference [20]. Agitators operate by creating a vortex in which air is mixed with the water. They produce a current of water which promotes uniform distribution [63, p. 15; 96].

Fish slime, regurgitated food, perhaps fecal material and deciduated scales promote the activity of bacteria [111] which may reduce oxygen concentration. Modern hatchery procedure [63; 72] uses a moderate starvation previous to transport to minimize regurgitated food. Filters effective enough to remove all of these materials do not seem to be in use; those that have been tried, though inefficient, were considered valuable [25]. A more efficient filter has been tested [61, p. 18], and the problem deserves careful thought in design of new fish transport units.

Another approach to the oxygen problem is that of reducing metabolism by drugs [1; 48; 49; 50]. Some of the drugs that have been used are: Sodium amytal [22; 62; 68; 69; 75; 82]; it is not effective in hard or saline water [48; 49; 64] because it is inhibited by calcium ion, MS222 (tricaine methanesulfinate) [50; 82; 105] is quite labile and is not recommended [50], but Groves (personal communication) has had good results with it at low temperatures. McMarland [50] recommends methyl parafynol (Dormison) tertiary amyl alchol (ethyl dimethyl carbinol), and chloral hydrate. Chloretone (chlorobutanol) and tribromoethanol are very powerful anesthetics, which McFarland also does not recommend. Urethane, which was once widely used, should not be considered, as it is carcinogenic [109]. Other anesthetics, such as quinaldine [60; 61] may be of value. Tranquilizers (Reserpine, raunormine and rauserfia) had no effect on the oxygen consumption of rainbow trout [68], but it was not reported if there was any effect on their activity during transport. (There seems to be some confusion in the literature on the drug methyl parafynol or Dormison. Chemically it is 3-methyl-1-pentyn-3-01, and apparently was also reported as methyl pentynol [67]).

Toxic effects other than simple anoxia may be due to carbon dioxide or to ammonia and other products of metabolism; to toxic products from bacterial action on such metabolic products, regurgitated food, feces, slime or scales; or to substances previously in solution in the water or dissolved from the container. The anesthetic properties of carbon dioxide are well-known [16; 30; 81; 84]. The effect of carbon dioxide in lowering the pH can also cause mortality [51; 100]. Many workers have reported the use of buffers. Inorganic buffers (sodium monophosphate, Na_2HPO_4) have given conflicting results [62; 85; 94; 101] when used in fresh water. An organic buffer, tris-buffer (2-amino-2-hydroxymethyl-1, 3-propandiol) gave good results [51] in transport of tropical marine fish.

The toxic effects of ammonia and other nitrogenous wastes have been reported by several workers [21; 27; 75]. Aeration does not seem to be effective in removing ammonia, and reduction of metabolism by cold and anesthetics is recommended by one report [75]. Certain resins have been reported to have the capacity of absorbing ammonia [62; 85], but others [65] have had negative findings.

Bacterial action, besides reducing oxygen concentration, may produce toxic substances and produce infections. Control of bacteria and fungus during transport has been done with chemical agents, acriflavine, calphomyein, and terramyein, as well as methylene blue to control protozoan parasites have been used [61], and tris-buffer also is said to inhibit bacterial growth [61].

Metallic ions have not been reported as a major source of mortality except for zinc [69; 70]. Under some conditions copper might cause trouble, and galvanized iron, brass, and copper should be replaced by appropriate substitutes. Other metallic ions do not present any serious problems, but they should be considered as a possible source of trouble.

Finally, organic solvents or plasticizers may dissolve out of painted surfaces; they may be extremely toxic at low concentrations. Thorough drying and preliminary washing of tanks is necessary, especially with some of the newer synthetic spray type paints.

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