swim bladder size. A major problem is that a fish's acoustic characteristics in regards to target strength and scattering properties are dependent on species, age, acoustic frequency, aspect angle and other environmental conditions. Assumptions as to acoustic characteristics of the fish are invariably included in signal processing.

The important aspect angle variable is often accounted for through geometry. By looking at the fish either from below or above, the presumption is that the fish is oriented horizontally. If a stream is being monitored by an acoustic beam pointed across the stream, the presumption is that the fish is perpendicular to the beam. In large ponds or cages, the orientation of the fish can not be assumed. Acoustic characteristics of even single fish are hard to determine. Many tests have been carried out (Shibata, 1971; Shibata et al. 1971; Peterson et.al., 1976) but the applicability of the data to unconstrained fish in their own environment is at least debatable. Even the down looking and up looking acoustic characteristics are not the same, with the uplooking having stronger signals.

The predominance of experience with acoustic systems has been from open water fish stock assessment (Welcomme, 1975) and stream monitoring. Acoustic stream monitoring was developed for situations where visual counts were not possible, such as turbid water or broad streams without counting passages. A bottom mounted acoustic fence was developed which placed the transponders across the stream looking up (Menirr & Paulus, 1975) and this system had accuracies as high as 95% relative to visual counts. Systems shooting acoustic beams horizontally across the stream have also been developed (Braithwaite, 1971 & 1975) . Both of these can have problems with drifting debris and bubbles in the water. Some of these error sources can be removed by sequential application of sensors and time of arrival data (distance information) to separate targets going upstream from those going downstream.

All these precedents with acoustic systems in open water and streams are not very helpful in culturing where the fish densities are usually much higher than in the prior situations. The signal integration technique based on a single scattering model (the total target strength divided by the assumed target strength of a single fish) is not valid at high densities due to acoustic attenuation by the fish themselves (Burcynski, et al., 1990) (i.e. the mass of fish alter the assumed acoustic transmission properties of the water). This citation specifically addresses the acoustic properties of salmon in high density culture and associated problems, including necessary changes in the acoustic models required to get valid results. Both up looking and down looking situations at high frequencies (120, 240 & 420 kHz) are addressed. This acoustical attenuation by the fish themselves would be applicable to the signal processing for the SIMRAD 160 System.

Another approach to the high-density culture situation, again salmon, is at the other end of the acoustic frequency spectrum at low frequencies in the range of 0.1 to 10 kHz (Lovik, 1986). This is the frequency range to get resonance effects from the swim bladders. The resonant frequency gives the fish size or fish-size distribution and the intensity of the signal gives an estimate of the total bimass. Both of these approaches work but are dependent on the accuracy of the assumed acoustic characteristics of the fish and on the validity of the assumed acoustic model. More acoustic data on fish under realistic conditions are needed. Also needed are comparisons of system outputs under culture conditions using various data reduction models with accurate number and size data acquired by other means.

The preceding acoustic systems have fixed transducers. One of the problems with high frequencies is that the beams can be dimensionally very small. This can provide high resolution but makes it impossible to have more than a very small fraction of the total population in the beam. The estimates for the total have to be derived from a subsample. If the fish are not distributed homogeneously or in a predictable pattern, these estimates could be highly inaccurate. This could be especially true in a large pond or cage and might require the transponder to be rotated, scanning the entire culture unit. Work is in progress to develop a scanning 420 kHz system with a 2 degree beam for use in catfish ponds (Derrow & Gilbert, 1989) . While a scanning capability increases the complexity and cost, it can give more accurate and complete data and the same unit can be shared by many ponds. This approach might be worth trying in cages if only one unit is needed. As in all acoustic systems, the specifics of the signal processing model would be critical.

Having discussed high and low frequency systems, the last acoustic technique is doppler shift. This is a frequency shift that occurs due to relative velocity along the axis of the acoustic beam. Doppler has been used to count fish (Menin & Paulus, 1975) and to eliminate false targets (Braithwaite, 1975), both with mixed success. Surprisingly, looking at fish from the side should give a zero relative velocity along the beam axis but the tail motion is sufficient to give a measurable doppler shift (Braithwaite, 1975) . Problems include surface waves, and turbulent water.

Another interesting aspect is that industrially available acoustic flowmeters, which work on doppler shift and are used to monitor flow in streams, have been noticed to give temporary "gliches" when salmon pass through them. This is currently being investigated by Terry Curran (604)363-6583 at Dept. of Fisheries & Oceans, Naimo, B.C. Canada. This raises the possibility that standard flowmeters with new signal processing could be used to count fish passing through ducts.

ELECTRIC COUNTER

Electrical fish counters work on the differences in electrical properties between the fish and the water (see next paragraph) . These differences in freshwater are about 1% and nil in seawater. Therefore, none of these schemes are likely to be practical in seawater. All seem to be limited to 1-D situations (where the fishs' orientation and direction of travel are known) . Two or three counters are often placed on the same duct to separate upstream and downstream passages. The signal strengths can be used to roughly size the fish into several groups. While the sizing is crude, it enables species and year classes to be distinguished where the differences in size or biomass are substantial. With suitable adjustments, they can be used to count very large fish, very small fish or even fish eggs, all with very high accuracy, sometimes within 1 %, relative to manual or visual counts.

Electrical units can operate on differences in electrical conductivity, on electromagnetic induction, where the fish's passage affects an imposed magnetic field, and time domain reflectrometry, where a fish's passage causes a perturbation in the impedance of a microwave transmission line. Only the conductivity and induction approaches have been used in counters, with the conductivity type the more common. The counter is one leg of a wheatstone bridge, which becomes unbalanced when a fish passes. Readjustments must be continually made to the bridge to compensate for slow conductivity changes of the water due to variations in flowrate, temperature and chemistry. Most conductivity counters are placed in ducts with relatively small dimensions relative to the fish to be counted and with many parallel ducts to allow sufficient water passage. There are data on the performance of commercially available conductivity counters (Smith-Root SR-1600, Northwest Marine FC-3) for counting of salmonid smelts. The technique has also been adapted to thin water flow over very wide crested weirs (Dunkley & Shearer, 1982: Walker & Beach, 1975) . While not yet developed, time domain reflectrometry also shows some promise for bottom mounting across rivers and economically counting fish individually (Mulligan, 1985) .

LIGHT & NEAR LIGHT FREQUENCIES

There are a number of approaches to counting and measuring fish based on the use of light or near light frequencies. The classic way to count and measure fish at a dam on a river is visually at a counting chamber and this is a 1-D process. This involves placing an individual with a hand click counter to look at the fish from the side underwater, sometimes against a dimensioned grid on the opposite side of the fish passage way. While expensive, this approach works reasonably well. Initial efforts to improve the process involved video tape. The emphasis now is on TV systems with computer pattern recognition (Irvine, et al., 1991). The viewing direction can be from the top, eliminating the expensive requirements for construction of fish passage ways and viewing rooms. From above, broad rivers, ponds and possibly even some cages can be monitored. Small organisms can also be monitored with this approach and, if used to look from both top and one side simultaneously, greatly increases information content (Ramscharan & Sprules, 1989). There are attempts to use this approach in culturing applications, including cages (Saage, Petrell & Neufeld, 1992) and flatfish on a solid bottom (Poxton & Goldsworthy, 1987). Peter Heyerdahl, of the Institute for Technical Services, Norwegian Agricultural University, is also believed to be working on optical systems using linear cameras to count and measure fish under commercial culturing conditions.

The problems with TV'S and computer pattern recognition involve not only the computer software but limitations due to water visibility, overlapping fish passages and penetration into dense aggregations of fish. Two viewing angles (side and top) can solve the overlapping passage problem but doubles the complexity of the system. The 3-D problem in high density culture, such as a cage, is obviously the toughest problem and not yet solved. TV systems, however, can be much better than the human eye, due to image intensifiers and/or IR frequencies to see in poor light and range gating (electronically looking at only the distance corresponding to the max intensity of a light or acoustic pulse at a given instant) to see through suspended particles.

Collimated light or IR beams and photo receptors have already been used in a number of commercial fish counters (see Existing Equipment section). As these sensors are relatively cheap, this approach could be extended to also give dimensional data on the fish, especially in a 1-D situation. An array of sensors would, by its nature, produce a pattern. Two viewing angles could be used. While the resolution would depend on the number and density of the sensor elements in the array and the system would probably not have as much information content as a TV system, it might be easier and cheaper. How this could be extended to a 3-D situation is problematical at this time.

The last optical method is the scanning laser radar. It works like a radar but at laser frequencies. It has substantial penetration in seawater and can give excellent resolution (Kronman, 1992; Treadwell,P.C. 1992) . The Biometrix 1000 system is reported to be of this type. This approach has many advantages but does not solve the occlusion problem in dense concentrations of fish. It is probably also too expensive for use in commercial culturing at this time. However, it is a relatively new technology, the costs may drop and some indirect way (probably an assumption combined with signal processing) of counting a dense aggregation of fish may be developed.

OTHER ELECTROMAGNETIC APPROACHES

Electromagnetic approaches at non-optical frequencies are limited. Radar frequencies attenuate very rapidly in water. Since ranges are usually very short, this, by itself, is not a problem. Three approaches have been suggested. One is using a continuous wave and letting the passage of fish alter the wave guide properties. Another is using an underwater radar and looking horizontally and, lastly, using a radar above water but looking down. These are all discussed in Mulligan, 1985. The problem is that to get a radar echo from a target (fish), its electrical properties must be different from that of the fluid. In freshwater there are some differences’ but in seawater these differences are dramatically reduced. The practical use of radar, even in freshwater, is problematical at best.

An interesting electromagnetic approach that might have some possibilities involves the white fiber action (myoelectric) potentials created by fish as they swim (Barham, Huckabay & Burns, 1969). These voltages are in the 0.01 to 40 microvolt range and have been used in fish counters in freshwater (Hartley, 1975: Beach & Walker, 1975) . These have been 1-D situations where the presence of a voltage spike is counted as a fish passage. In a broader context with an aggregation of fish, possibly even in a 3-D situation, the signal strength could be interpreted as a level of activity, which may or may not have value in management.

In spite of the low voltages involved with the myoelectric approach, the problems encountered have not been in picking up the signals but in electrical interferences. This is in the form of waterborne AC currents induced by power lines and switching transients. The power line frequency currents can be suppressed, but any imperfections in the filtering devices can produce high-order harmonics with characteristics similar to those of the action potentials (Beach & Walker, 1975). It is possible that clever sensor packaging and shielding might solve the interference problem. Another problem is the relatively high electrical resistance of freshwater, which requires the sensors to be very close to the swimming fish. In this case, this approach should be much more attractive in seawater due to the reduced signal loss with distance, if the background noise is no worse. There is no known work with this approach in seawater, althouqh it has promise as a relatively low cost sensor.

INFORMATION SOURCES

Part of this study was to find out what equipment was commercially available world-wide for counting and/or measuring fish *in situ.* It was decided early in the project to identify all available equipment, even if what it did was only tangentially related to the main intent of this study. Several different but complimentary data gathering approaches were implemented.

One was using yearly buyers' guides and industrial newsletters to identify distributors. The "Buyer's Guide 92 & Industrial Directory" from Aquculture Magazine had nine listings under "Fish Counters." Another source was adds or short articles in aquiculture and fishery magazines. Some of the publications which were spot checked included Aquaculture Magazine, Fisheries Product News, Water, Farming Journal Aquaculture and Fish Farming International

Developments in Northern Europe and in Japan were of particular interest, due to the advanced status of their aquiculture industries. About 30 letters were sent to each of these areas. In letters sent to research organizations in these areas, asking primarily about past and on-going research, there was also an inquiry about commercially available equipment. The response from Northern Europe was fairly good, and in a few cases excellent. In contrast, the response from Japan was by and large rather poor. The only-tidbits from Japan relate to a well funded industrial consortium doing research and development in the are& (see technical section) . It was also learned that a company called SIMRAD, which is very active in Scandinavia, is also working in Japan on related research. SIMRAD's work in Japan, according to SIMRAD USA, relates to open sea fish stock assessments using scanning acoustic systems.

Each lead was pursued, the ones in North America primarily by telephone and over seas by letter. Each contact was asked about possible uses of their equipment, possible future improvements, their outlook for the market and about other approaches or available equipment. About half those contacted were only distributors. While very cooperative, many had little understanding of how the equipment worked or of the actual performance of the equipment under operational conditions. In a few cases, direct contact was attempted with the actual foreign manufacturer and usually it was unsuccessful. Table 5 contains the results of this survey of commercially available equipment. If the manufacturer is not the same as the North American distributor, the country and address of origin is given in the first column of Table 5. The North American representatives and their address are given in column 2 of Table 5.

CONDUCTUVUTY/RESISTIVITYCOUNTERS

Some of the Smith-Root and Northwest Marine equipment are based on conductivity differences between fish flesh and water. While small, in freshwater it is sufficient to get a good signal on a fish passing close to the sensor. These devices are routinely used in freshwater hatcheries, and if used properly are quite satisfactory. However, the Conductivity differences between fish flesh and estuarine or marine waters is nill and this approach will not work under these conditions.

TABLE 5 COMMERCIALLY AVAILABLE FISH COUNTING and/or MEASUREMENT EQUIPMENT

NAME/TYPE	MANUFACTURER/DISTRIBU'	COMMENTS
Advanced Fish Counter	Northwest Marine Technology, Inc. Shaw Island, WA 98286	Conductivity sensor, measures range of fish sizes by selection of tunnel diameter up to 1 in. Fresh water only.
Model SR-1600 Electronic Fish Counter	Smith-Root Inc. 14014 N.E. Salmon Creek Ave. Vancouver, WA 98686	Conductivity 16 tunnel, 1/4-3 in. diameter. Maximum count of 10 fish/second.
Model-1100 Fish Counter	Smith-Root Inc. 14014 N.E. Salmon Creek Ave. Vancouver, WA 98686	Conductivity tunnels 1-12 in. diameter Counting rate of up to 5 fish/second. Fresh water only.
ES-2000 Hydroacoustic System	BioSonics, 3670 Stone Way North Seattle, WA 98103	Versatile fixed site fish tracking and counting system. Frequencies from 38-420 kHz. and 16 transponders. Used in fresh water and marine entrainment studies.
Passive Integrated Transponders (PIT) Tags	BioSonics, 3670 Stone Way North Seattle, WA 98103	Electro-magnetically interrogated fish tag with 34 billion possible I.D. codes. Variety of detection sensors available.
Passive Integrated Transponders (PIT) Tags	Northwest Marine Technology, Inc. Shaw Island, WA 98286	Over 400,000 specimens tagged worldwide, marine/fresh water and wide range of fish sizes. Can be read visually by an x-ray. Flexible system with many options.

TABLE 5 COMMERCIALLY AVAILABLE FISH COUNTING and/or MEASUREMENT EQUIPMENT

NAME/TYPE	MANUFACTURER/DISTRIBUTOR	COMMENTS
Submersible Biomass Counter (SBC), Vaki-Aquaculture Systems Ltd., Reykjavik, Iceland	U.S. distributor: Zeigler Bros., Inc. Gardners, PA. 17324-0095 Canada distributor: Marel Equipment Inc., Dartmouth, N.S.	Light emitting diode fish counter and biomass assessor. Rechargeable 12-V battery powered. For use in cages, but prior use and practicality uncertain.
Bioscanner Fish Counter V-Channel Vaki-Aquaculture Systems Ltd., Reykjavik, Iceland	U.S. distributor: Zeigler Bros., Inc. Gardners, PA 17324-0095 Canada distributor: Marel Equipment Inc., Dartmouth, N.S.	V-shaped channel with light emitting diodes on each side. Counts only. Power supply 220-V or 110-V, 50/60 Hz. standard, 12-V DC optional. Model-1, fish sizes from 3-750 g. Capacity 25 k 10 g. fish/hour. Model-3, fish sizes from 0.5-600 kg. Capacity 5,000 2 kg. fish/hour.
Model PEC-84 Photoelectric Fish Counting System	Smith-Root Inc. 14014 N.E. Salmon Creek Ave. Vancouver, WA 98686	Opposed infra-red scanners. Fish from 1-8 in. length. Out of water use. For hatchery hand counting, counting rate of 1 fish/second.
Fish Cage Monitoring System FCM 160	Simrad Inc. 19210 33rd Avenue West Lynnwood, WA 98036	200 kHz IBM compatible system for up to 16 cages. In commercial use.

TABLE 5 COMMERCIALLY AVAILABLE FISH COUNTING and/or MEASUREMENT EQUIPMENT

NAME/TYPE	MANUFACTURER/DISTRIBUTOR	COMMENTS
Lumic Fish Counter BIS Vekter og Veisystem A/S P.O. Box 208 Paradis/Bergen, Norway	North American Distributor Lofoten Aquasupply P.O. Box 5684 Victoria, B.C. Canada	Lumic fish counter in use currently in Scandinavia since 1989. Above water use. Four models cover range of 25 g to 6 kg. Fish interrupt light beams.
Aquascan Fish Counter	Torbjorn Kvassheim Gosenstien 1 N-4041 Hafrsford. Norway	Photoelectric system using charge coupled devices. Fish 3-600 g. Above water use. Often connected to fish pump. [illegible] use in Scandinavia.
Biometrix system-1000	Advanced Biometrics Ltd. 6020 Stevestow Hwy P.O. Box 63058 Richmond, B.C. Canada V7E 2KO	[illegible]tral narrow Bandwidth under [illegible]nning laser (LIDAR),counts and [illegible]s, flexible as to conditions of [illegible]nd off axis photodetectors (up

TRANSPONDERS

The PIT (Passive Integrated Transponders) are currently used in fish stock assessments, primarily in streams. Each individual tag costs about $5 but allows individual fish to be identified. The fish must pass close to the sensor for detection. The applicability of PIT tags to commercial fish grow-out and the associated economics is certainly questionable at this time. Monitoring the progress and fates of a relatively small number of individual fish within a much larger population could be used with statistics to get high confidence data on the numbers and size distribution of the total population. State-of-the-art papers on PIT systems and other types of tags are included in The Proceedings of the International Symposium on Fish Marketinging Techniques(Parker, et al., 1990). This approach is included because it does work and it may have immediate value in commercially based applied research projects. In fact, the Norwegians are using small acoustic transmitters to track individual salmon in large culturing cages, to better understand fish distribution and behavior as a function of stocking density, feeding activity and environmental conditions (Juell, 1993 A) .

PHOTOELECTRIC COUNTERS

The Smith-Root PEC-84 infrared counter is intended for small-scale hatchery or research use. It is for relatively small fish that are dropped by hand into a tray at the top of the counter and fall through to be counted. There was information to indicate that there existed an infrared counter of German origin in commercial hatchery use in Northern Europe (Fischtechnik Fredelsloh GMBH, Forellenhof, 3413 Moringer 1, Germany), but no response or confirmation was found.

An infrared counter, based on an available intruder detector arranged to count obstructions lasting longer than 40 ms, has been developed for hatchery use (fish 10-21 cm long) . It is very cheap and provides numbers within 2% of hand counts (Ewing, Evenson & Birks, 1983). These tests were one dimensional, included about 12,000 steelhead trout and the numbers from the detector were both above and below hand counts. The alignment of the infrared source and the photocell were shown to be critical.

The Vaki V-Channel fish counter is claimed to be in commercial use in several hundred salmon grow-out operations world wide. It is used above water and counts only. It is usually used after fish pass through an above water grader. The V-channel with flowing water assures fish pass singly by a double row (each side of the V) of light emitting diodes (LED) . The Biomass scanner from the same source (see Table 3) and using the same approach, appears to be only a test item. It is square with LED's on two sides and is shown on company brochures submerged in a fish cage. While it probably can "count" fish, the count may be meaningless. The "count "would be the number of fish that decide to swim through the sensor. The percentage of the total population that may feel like swimming through, over any given time interval, is unknown. In addition, there are no indications how the problems of Table 2 are to be addressed or even if it is a 2-D or 3-D situation.

The Lumic Fish Counter is very similar to the Vaki V-channel. It also uses light beams intended for above water use and counts only. It can be used downstream of a grader. There are four models of fish counting units covering the weight range from 25 grams to 6 kg. The smallest model has 14 counting channels (tubes for the fish to swim through) and the largest has two. A controller module can handle up to three counting units. Rates to 30,000 fish per hour can be counted. Well over a hundred systems are in commercial use in Scandinavia since 1989. Only very recently has it become available in North America, but 3 units have already been sold to commercial fish culturists for hatchery use. The company is very interested in placing some of the larger units at commercial grow-out sites in North America (contact: Nils Skulbru, Lofoten Aquasupply, (604)598-4225).

The Aquascan Fish Counter is a very new counter presently in limited use for counting smelts in Scandinavia. Fish are pumped with water to a basin at the top of the unit. The fish drop through a wide but relatively narrow slit. The fish go through the slit with flowing water at all angles, at high rates and with no apparent damage. This system is clearly intended for commercial use. The sensor in the current version is above water but the system would probably be readily adaptable to an underwater unidirectional situation (i.e.. included in a duct) . The slit is a very simple but elegant way of solving some of the problems of 1-D systems, which have in the past used variable tube diameters and many sensors in parallel. The slit, while solving the problem of overlap, is not as restrictive on water flow through the counting zone and only requires one set of sensors.

ACOUSTIC SYSTEMS

The BioSonics ES-2000 is an underwater acoustic scanning system used in fish tracking and counting applications, such as at dams, power plants and industrial facilities. It is a modular and flexible system with a number of options which can be assembled for specific applications. It might ‘be adaptable to commercial fish grow-out, but the fish densities in culture are probably much higher than normally encountered and the economics are questionable. The BioSonics Manager for Imaging and Tagging Products is Jeff Condiotty ((206)634-0123).

Of the presently available equipment and systems, the SIMRAD FCM 160 Fish Cage Monitoring System is the only one specifically designed for commercial culturing operations. It is an acoustic system with a single fixed transponder at the bottom of each cage looking up (max 16 cages per system) . The high frequency (200 khz) gives a relatively narrow beam and high resolution. The key to its performance is signal processing software. The program prints out both numbers and size distributions and shows the fish distribution as a function of depth. How good these numbers are remains to be demonstrated. The comparisons of system outputs with accurate data on numbers and size distribution acquired during grading and counting have been promised but not yet received.

Serious work started on the SIMRAD FCM 160 system in 1989 and the first deployment to a commercial cage culturing site was in December 1991. It is now an available product and is presently being tested at three commercial trout and salmon cage culture sites in Norway, the last being installed in June 1992. The system monitors three to six cages at each site and includes both round and square cages and a range of cage sizes, but no very large cages. Cage water depths range from 6 to 20 meters and the size of the trout and salmon about 120 grams to over 3 kg. Fish densities are unknown but presumed to be in the normal culturing range of values. Hardware, transducers, and software continues to improve during the on-going testing program. While quantitative results are currently lacking, it is claimed to be effective in counting and measuring fish in *situ* and also in detecting unusual behavior (i.e. fish distribution) . Three articles have been published about the system by the fish farmers and translations into English will hopefully soon be available (citations unavailable). Two of the operators are reported to be negotiating for outright purchase of the system. While quantitative information on performance in different situations is not yet available, these data are now being collected. The accuracy of the system, as a function of fish size, fish density and cage size, is of particular importance. SIMRAD is interested in developing the North American market for this system and its derivatives (contact: Egil Gammelsrod, SIMRAD USA, (206)778-8821).

LASER SYSTEMS

The Biometrix System 1000 is a laser based system which appears to have been designed for the same requirement as the acoustic based BioSonics ES-2000. It has scanning lasers with both on axis and off axis narrow band photodetectors. It is placed underwater and is usually aimed in a more or less horizontal direction. This unit can scan about 120 degrees and its calorimetric capabilities are best used if it can see the sides and top of the fish. It can identify fish by species based on differences in spectral properties and it can both count and measure fish. A Model 1500 for submerged use, with multi-parallel pulsed laser beams, is under development which can scan up and down and over an angle of about 180 degrees. Both models have a choice of laser frequencies and a number of system options; including number and placement of receiving photo diodes. A mobile version that could be dipped into the top corner of a fish cage is being considered for development and the company is actively seeking partners for this effort. A single sensor system might be usable with a large number of cages and even “shared between sites. This new model would be specifically directed towards fish culturing applications (contact: Steve Oura, Advanced Biometrics, (604) 276-2497) .

While the Biometrics laser approach has not yet been demonstrated with fish densities common in culturing applications, there is some optimism that they might prove successful. As in the acoustic case, signal processing and data reduction software can be critical. The practicality of such light detection and ranging (LIDAR, also called laser radar) systems in commercial fish grow-out and associated economics are still questionable at this time. However, these laser systems are relatively new and the technology is far less developed than the acoustic option. Performance and cost may dramatically improve in the future. Even a very expensive system may be practical if it can service many cages.

EVALUATION AND RECOMMENDATION

Evaluations and recommendations should be separated into time frames of immediate, short term and long term. For the very short term, the only methods possible are those that are already in use and the equipment available. For freshwater hatcheries the conductivity type counters work well, such as the Smith-Root counters. For commercial cage culturing, this is limited to out of water counting usually combined with an available grader. This would include the Vaki, Lumic and Smith-Root fish counting units, all of which are in wide spread commercial use.

For short-term use in cages, the SIMRAD system is of considerable interest. While the equipment is already available, its performance in a commercial context is not yet established. While the acoustic returns are related to sizes and numbers, the signal processing assumptions used in dense concentrations of fish remain to be verified. Cage size, fish size, fish density and a large number of other physical and biological factors could significantly affect the readings. At this time, there is no way to evaluate the accuracy or consistency of the outputed values. Monitoring field use of this system and even possibly buying or subsidizing one for testing in a commercial framework is strongly recommended. The address of the North American distributor is on Table 5 and the persons to contact are Egil Gammelsrod or Chris Hancock (206-778-8821). They are very interested in developing a demonstration project in a commercial culturing context somewhere in North America.

Another short term option is to modify some of the proven above water unidirectional approaches for use in an underwater or *in situ* unidirectional situation. For this to occur, the fish would have to be encouraged to swim through some sort of constriction with a sensor installed in it. An obvious and beneficial combination would be in connection with an *in situ* adjustable bar grader. The slit system inherent in the Aquascan unit may be most adaptable to this application. There may be a number of clever ways to force fish unidirectionally through an in-water sensor, which would be acceptable in terms of cost and employment effort. Research and development along these general lines is strongly recommended.

Another approach, that shows promise for unidirectional *in situ* counting, is based on small myoelectric voltages created by swimming fish. This sensor approach is not as established as those referred to above but does have some prior use in freshwater. This approach has never been evaluated for use in seawater, but it should have some advantages over use in seawater. It might prove to be cheap and effective. This would be a good Graduate Student project.

For the longer term, TV combined with computer processing, acoustic systems based on swim bladder resonance, and LIDAR systems all show potential of solving the high density culturing 3-D counting and measurement problem. In particular, the fact that swim bladder resonance research (Lovik, 1987) is being supported by SINTEF and is directed towards cage cultured fish in Norway, is sufficient reason to believe that it has some potential in commercial culturing applications. Investigating the potential in this area would also be a good graduate student project, but probably at the Ph.D. level and possibly requiring a considerable amount of specialized acoustic equipment and facilities. In regards to LIDAR systems, the Biometrix LIDAR systems might be adaptable to cage use. While undoubtedly expensive, a single mobile