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AN INEXPENSIVE MICROCOMPUTER BASED DATA RECORD-KEEPING SYSTEM FOR THE INDIVIDUAL FISH FARM

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Abstract. The basis of any effective business planning is good information. Fish farmers in particular need continually to adapt their production policy according to the performance of their stock and changes in the market conditions. Accurate knowledge of stock performance requires detailed record keeping but this can be time consuming and frequently is made to take second place to other tasks in the day-to-day running of the farm. To minimise collection time and errors, a microcomputer based system was tested which recorded environmental and stock data in a standard form presenting the results in a daily, or weekly format, as required, with all arithmetic calculations completed by the computer. Data was stored on electromagnetic disks and as hardcopy in files. This is adequate for efficient record keeping and reduces the man-hours required significantly, but more importantly, accurate data are made available easily, at any time, for further analysis and business planning. The microcomputer chosen, the Sharp 1500A pocket computer, was the lowest-priced, suitable machine. Programmed in BASIC language it held up to one week's data, collected daily, and performed calculations on these. Data were downloaded, via an interface, to a simple printer to give a system adequate for small farm needs. In addition successful down-loading, via a telephone modem, to an IBM PC desk-top computer was used to establish a system where several data collectors, used in remote locations could feed information to a central management office. After transmission, LOTUS 1-2-3 software was used to analyse and store the data.

Keywords. Microcomputer; fish-farm data; record-keeping system.

INTRODUCTION

In order to retain good management control over the complex system of a fish farm and to be able to respond effectively to changes in farm conditions, stock performance and market fluctuations, it is vital that a fish farm manager has accurate, up-to-date data to guide him. The availability of low cost, powerful microcomputers has enormously improved the opportunity to collect, store and use business data so that fish farmers can easily collect and process all the data required to make effective decisions even within the small amount of time that more immediate management tasks usually leave for this purpose. Such a microcomputer based data system would capture the data on site for subsequent analysis and storage, and provide easy retrieval of records whenever needed.

The system that we describe here was designed to minimise most of the burden of physical data capture and to input into a computerised system which further evaluated, analysed and subsequently stored the records in the form of organised electronic files on magnetic 'floppy' disks. It took advantage of the most recent information technology at an economically feasible scale for the average fish farm. Its design was based on easy to use and flexible 'off the shelf' software with only a small additional amount of custom built programme encodement. Clear documentation and definition of assumptions was provided to enable easy maintenance and any minor adjustments needed for different fish farms to be carried out. The hardware selected, apart from being able to cope with specific software needs, must also comply with such basic criteria as long term maintenance support by the supplier, existing wide user base and reasonable costs. Although the data system is built around specific hardware this is by no means restrictive. As far as the system's qualities are satisfied other, - possibly better - hardware can be used at own choice. Nevertheless, because of the number of initially successful microcomputer systems which subsequently have disappeared from the market, the choice made for this project, was of the most popular hardware system (IBM) using the most popular software system (Lotus 1-2-3), a "mainstream" philosophy.

MORE ATTENTION TO FISH FARM RECORDS NEEDED

For the purposes of this paper 'data' simply means facts, observations or occurrences, usually given as figures resulting from measurements.[1]

Examples would be:
- readings of water temperature,
- measurements of water pH, dissolved oxygen,
- number of feeds per day,
- amount of fish biomass and number of fish in a container.

'Information' results from the processing of these data. If it is of proper quality, it facilitates decision making and planning on the part of management. By 'data processing' we mean the assembly, distillation, analysis, comparison, summary, tests and rearrangements applied to data giving to it a meaningful form in order to extract useful information from it.

Examples would be:
- the summer water temperatures on average were lower this year than during the similar period last year,

[1] Data may also be presented in the form of words, or codes, or special symbols (eg. fish sex: ♀), or any type of graphic representation.

- when the dissolved oxygen content of water drops, less feeds per day are provided for the fish.

Although accurate and valid data removes much of the uncertainty which surrounds operations and its use in efficient decision support is widely acknowledged, the attention paid by fish farmers to providing it is usually small. Recording is a difficult task to be practiced under the harsh fish farm environment and any records that are kept should be profitably used. Recording incurs costs as well as providing returns. The costs consist primarily of the value of the time and effort of the fish farmer and his labour force, which could have been used for other work on the farm or for leisure (opportunity cost). Therefore, after establishing a clear idea of the purpose for which data is needed, priorities must be established in determining what to record and a sufficient degree of flexibility retained in order to permit new data to be collected if the need arises (C.S. Barnard, 1975). Serious consideration must be given to data quality in terms of accuracy, relevancy, compatibility to the purpose in hand and comprehensiveness.

FISH FARM PHYSICAL DATA

In any aquaculture facility the following identifiable major components affect its productivity (Klontz, Brock, McNair, 1978):

- fish,
- water,
- container,
- nutrition,
- management (e.g. feeding schedule, grading policy etc.)

Each has one or more interactions with each of the others and each consists of several unique factors that may not necessarily be present individually at any one particular facility. The factors associated with each major component can, in most cases, be quantified. Also, each factor must be considered as having either a cause or an effect role in relation to one or more other factors. Altering one of them in an aquaculture facility may have indirect as well as direct effects on one or more major components.

WHY RECORD THE DATA?

Through up-to-date records it is possible to identify the *current state* of the particular fish business's affairs, its environment and operations. *Key success functions*, like the fish food conversion rate (FCR) or the fish growth rates, are identified and then subsequently measured, so that the farm's performance and capabilities in these key success areas are assessed. The historical records, held in the "data bank", can be compared with current figures to assess performance at any point in time.

Since decision support is the major role of data and information, what needs to be recorded depends on the *decision purpose*. Three main purposes suggest what records need to be kept (Barnard and Nix, 1979):

- to check on performance. It is only through good records that a check can be made on how performance has compared with past plans.
- to guide tactical decisions. Records should reveal the degree of technical efficiency of the various production operations and highlight weaknesses that must be removed as part of short-term management.
- to provide planning data for strategic, long term decisions when making or revising future plans.

THE UNIQUE NATURE OF THE FISH FARM

There are many individual variations in design and product mix of different fish farms, giving each farm a uniqueness which creates problems in deriving generalised planning models. Farm designs are major cost and productivity determinants and, in practice, farms operate on a combination of systems the evolution of which under new, improved designs is a continuous process. Even so, a flexible recording system can be designed for farms in general, which defines what data to collect, how to capture it and by what means, as well as how to process and present it. This is then individualised so that the unique identity of a farm is taken into the model and the manager arrives at representative data which suit his particular decision making needs.

CAN MICROCOMPUTERS HELP?

Computers perform the most complex of operations in practically no time, store and retrieve data effectively, and have tremendous flexibility of vital analyses (listing, sorting, comparing) and presentation (graphs, etc.). The major technological advances in the field of microelectronics have made the applications of microcomputers in relatively small businesses,such as some of the smaller fish farm units, a feasible consideration because:

- powerful 'micros' are now affordable,
- there is a great variety of flexible "off the shelf" software programmes to choose from,
- microcomputers and programmes are now very easy to use by non experts ('user friendly'),
- useful complementary options, such as computer communications, are available at low cost.

It should be obvious that computers process whatever figures are entered without any reference to or acknowledgement of their quality. The value of the calculations depends on the validity and accuracy of the data input and this accuracy, ultimately, is down to people not the machines.

WHY A COMPUTERISED RATHER THAN A MANUAL DATA RECORDING SYSTEM?

Sound data records are invaluable for good decisions but very hard to organise. Manual systems attempted on individual fish farms are frequently abandoned because the time and effort required for them is not felt to be balanced out by the perceived benefits. It was found that in several cases data figures were recorded on paper sheets which became unreadable with time and only in the best cases was there a standard form of records kept. Record sheets were piled up in fish farm offices only to indicate the effort that had been wasted on them. After all not all 'sharp' managers are also neat in their 'homework'.

Personal computers are to be preferred to even good manual record systems because they are efficient at:

- capturing field data on site (hand-held devices - communications),
- consistent, standard[2] record keeping,

[2]The same data elements collected at defined time intervals using the same methods.

- storing neatly organised records,
- easy recapitulation of past records,
- very fast calculations and unlimited recalculations,
- making no errors or miscalculations,
- avoiding paperwork,
- better presentation of results,
- making time savings.

In summary, it is possible to relieve the burden of field data capture, make exhaustive analyses of the appropriate current or historical data with less effort, present results in the most suitable form, and make substantial time savings.

ECONOMIC CONSIDERATIONS

The total estimated costs of implementing a microcomputer based data system can be divided into one-off costs, associated with acquiring the system, and running costs that will recur throughout the life of the system such as hardware and software maintenance, upgrading etc.

It is recognised that one of the major cost items is the time devoted to system development by the manager responsible for the farm, and *the opportunity costs of the time of managers* may be heavy. It is important to envisage how and to what extent other people should be involved and the amount of time the manager can afford for them to train and practice. Attempts to evaluate the opportunity cost of the manager's time, or of any other member of his staff involved, are risky and *subjective* because different people think of their time differently. It is a fundamental necessity for the fish farm manager (or whoever the user may be) to devote some time to familiarise himself with the operation of his system. The more he knows about his computer and his data system, the more he will benefit, and in general, people will do better if they are both motivated and trained. Getting to know the system is not a one off operation but requires continuous commitment and some initiative by the operator. Nevertheless, it is interesting to note that possession of a system often creates a form of addiction such that many evenings are spent in exploring it to the exclusion of other leisure activity!

Normally it is the benefit that is very difficult to quantify. Sometimes, it may be relatively straightforward to calculate cost savings in terms of the time of staff involved, but the assessment of benefits becomes more difficult at higher management levels where cost savings become less apparent and *improved performance* may instead form the justification for the new computerised data system. For example, quicker and more effective implementation of plans.

Some information was traced from some, mostly large, fish farms which had invested in computer systems in order to automate various (mainly secretarial) tasks, such as word processing, invoicing etc., but, apart from the purchasing costs of computer hardware and programmes no precise evaluation of these systems was ever attempted by their users nor was it known whether they had realised all of their system's potential. The encouraging fact, however, was that those fish farmers involved in computers were keen to proceed further to upgrade their systems, which indicated their positive feelings toward the computerisation of at least some specific tasks. After all it is up to the individual manager's personal feel of the situation whether to adopt computerised techniques or not and consequently whether to invest in them.

ADOPTING DATA COMPUTERISATION

A microcomputer based data system requires two fundamental concepts to be understood by its ultimate users. First the vital necessity of organising a comprehensive data record system to be used in decision making. Secondly the need to apply computer technology to derive as much information as possible from the data to form and test decision options. In order to proceed with the development of a system for a particular farmer, active participation and cooperation is needed. However, unless it is possible to give information on the costs and benefits based on actual experience which has been obtained elsewhere, it is often difficult to secure this initial commitment. In the early stages of this particular project there was often the feeling that records were generally useless as a result of previous abandonment of past, unsuccessful, manual systems. Relatively capital constrained fish farmers needed clear cost-benefit calculations to appraise their investment and these were impossible since most benefits could be quantified only after some experience at the particular site and with a subjective view of the farmer's valuation of his own time. Breaking this 'circle', by securing the wholehearted co-operation of a farmer as a 'gamble' on his part, was the turning point which enabled the first system to be installed and proved.

To illustrate the problem, it is useful to distinguish between two broad categories of fish farms.

First, there are the relatively small holdings with less working capital involved in fish production. The manager on these farms, who may also often be the proprietor of the business, is totally responsible for all decision taking and controlling of all processes on the farm. His decisions are taken out of his own experience, and since his holding is small enough he may be able to maintain sufficient control over his business in order to keep it viable. Because of his lower capital resources he will tend to allocate a greater proportion of them to conservative investments so as to ensure some degree of return as losses are much more painful for his vulnerable business compared with a wealthier one. It is also possible that he puts more stress on intrinsic aspects of work, that is, he is relatively more concerned with personal fulfillment and an independent lifestyle.

Secondly, there is the category of larger holdings with substantial working capital tied up in the business. Under such circumstances even marginal mistakes or foregone opportunities may prove very costly because of the scale of the operations. The manager usually needs to justify his decisions and actions and present his results to his superiors in the management hierarchy who expect to maintain their business profitable and, if possible, expanding. Management needs to be exercised rationally and close control over the business operations is needed. Since the holding is big enough it possibly employs several people to carry out various tasks. Therefore, there is a definite need for information and information feed-back, flowing from the field towards the centre of decision taking, and vice versa, in an organised speedy manner in order to coordinate these various tasks under the different spheres of responsibility.

Obviously, it is this second category which provided the most fertile ground where the idea of pioneering a fish farm information system could be applied. In fact most of these big farms did operate at least manual record keeping systems, while others had gone some way into computerising clerical tasks. The need for a consistent data system was recognised, and the proprietors or higher standing managers of such businesses who decided upon investments, did have the capital resources required. They usually also had the willingness to undertake risks in promising projects because they recognised that to expand or even to keep their present state of business they needed to keep up with technology and modern methods if not to pioneer new ideas. Managers appointed to such big scale businesses were knowledgeable people with experience and some formal education in a relevant field of aquaculture, management, etc., and there were more possibilities to have a constructive open approach towards innovative ideas.

From the above discussion we may identify the features of a fish farm which is most likely to develop, implement, and test a computerised data system.

- relatively big business with enough capital to invest in new developments.
- management committed toward business growth and profitability.
- managers who are experienced, educated and open minded to new ideas.
- managers who are willing to take some risks at least as far as their time spent.

At the completion of these first detailed studies it should be possible to demonstrate the value of undertaking such an investment and effort, particularly to small farmers who are short of capital and sceptical. However, no matter how successful a system may prove to be on some other fish farms, *unless the manager is determined to take an active part in the development of his own business's management information system, the fundamental idea of having a representative system on the specific farm, totally mastered and controlled by the decision maker himself, cannot materialise.*

COMPUTER PROGRAMMES THAT MAY HELP

When thinking to apply information technology in management practice, the first decisions to make concern *software* - the instructions which tell the computer what functions to perform. There is little to choose technically between different makes of computers in a given price range, but not all of them accept the software needed. Therefore, it must first be examined, in great detail, what tasks the computer should perform.

The most directly accessible and relatively cheap is "off-the-shelf", packaged software. It is bought as a package, comprising a programme (or set of programmes) usually on floppy disk, and documentation explaining how to use them. There are two broad classes of packaged software: firstly Specialist, (or Vertical market), software. This is aimed at a specific set of users in a particular industry or profession, such as estate agents, general practitioners, farmers etc., and, secondly, General purpose, (or Horizontal), software. This aims to solve one general problem for a wide range of users from any industry or profession. This category includes spreadsheets, wordprocessing programmes etc. Very often either of these types could be suitable and for example, a general spreadsheet programme for, say, financial calculations and a specific dairy farming package could both be very useful on a dairy farm.

Moreover, it is likely that more than one type of general purpose package will be needed to meet all requirements, and this had led to a growth in 'integrated packages', which provide several general purpose functions, for example, spreadsheet, graphics and database in one package.

However, it is not to be expected that even the specialist application packages do exactly what is required, so, the general purpose and especially the integrated programmes, are able to be adapted to any needs. In addition, the integrated packages are relatively cheaper than the specialist ones since they are directed at a much broader market. Apart from the price, however, there is also the need for long term support, that is help and programme improvements provided by the software company. The number of existing users of the package provides some indication of the level of support and experience expected. The commonality of documentation and appearance of the different functions to the user is also a benefit. The documentation of an integrated package usually has a common design and presentation for each of its integrated modules with good cross referencing between applications. Far more useful though is the common 'face' which each application of the package presents to the user, because even simple things like the functions of the same keys on the computer keyboard can vary tremendously between different packages. As a consequence there is a much shorter learning curve than if applications, such as spreadsheet, database and wordprocessing, are all obtained from different packages as would be the case if a non-integrated system were in use. However, more important than these, data interchange, along with the adaptability, is perhaps the main advantage of integrated packages. It is possible to switch instantly and link data automatically between applications. So, a graph of the data stored in a spreadsheet may be created within seconds! Additionally, software producers have made it possible for the most popular packages to interchange data between them and generally to 'give away data', a fact which sets the computer user free from any specific programme. In summary the advantages that integrated software packages offer are as follows:

- Directly accessible for purchase,
- Cheaper,
- Long term support and advice,
- Detailed, versatile documentation,
- Commonality of documentation,
- Commonality of the presentation of their different applications,
- Data interchange between applications (modules),
- Data interchange with other popular packages.

The other big category of computer software is that of "Bespoke" or custom built software. This is where systems analysts and computer programmers from a software company will create a package especially for a particular firm and it is, consequently, very expensive. It may be useful in cases of fairly standard applications where existing packaged software is not sufficient, but very careful appraisal of such a costly investment is needed.

Because fish farming has unusual requirements, and is not yet adequately covered by specialised packages, an appraisal was made to see whether the facilities that were required could be put together from a general purpose package. The more wide-ranging and the more powerful the facilities offered by any package, the more likely it would be that it would cover the requirements and also be capable of minor changes by the operator if necessary.

It is in the nature of any business to change and it is good practice to be able to make any changes needed smoothly. Wherever custom written code must be used, it is usually extremely difficult to adjust the design unless it is clearly obvious through its documentation. There are many examples where reliance on a custom built software system has been a major factor in delaying a much-needed change in a business due to the added cost and upheaval of modifying or rewriting the software.

Therefore, the 'golden rule' throughout this study was: *Buy "off the shelf" and subsequently adapt. Keep bespoke code to the minimum, and keep it as simple and as clearly documented as possible.*

THE DEVELOPED DATA SYSTEM

The Software and its Functions

The specific needs perceived for the data capture and record systems to be used could be satisfied by the use of a powerful spreadsheet and graphics package supported by a small, custom written, programme suitable for data capture on site. Since it was decided that a handheld data collector and a desk top personal computer were required, which, in addition, should be able to communicate as a part of the system, a communications' package was also part of the software requirements.

The custom built programme was to be used for direct input of raw data which would then download, via the communication's package, to a specifically adapted worksheet of a powerful integrated package offering a spreadsheet, a data base and graphic facilities. The spreadsheet would accept the data, analyse it and store it in data files on floppy disks. These files would then be retrieved from the disks at will and the data displayed, "What if"/sensitivity analyses could be performed and the data printed on paper with the desired format. The graphics application would make available various types of graphs to illustrate trends which could also be printed. These graphs would be automatically updated as new data were entered into the file.

The Hardware

Firstly, the equipment was identified from what was currently available in the marketplace which conformed to the conception of the system's design. The following equipment was necessary:

- a desk top microcomputer,
- a printer,
- a hand-held 'pocket' device,
- two modems,
- connecting cables,
- floppy disks.

Secondly, the performance criteria of these individual items were specified. This was determined by analysing the scale and type of the fish farm, the amount of data which was likely to be processed, the cost restrictions imposed and, in the case of the computer operating system, its ability to run commonly available software of the sort under consideration. The minimum needs that were eventually defined for each one of the hardware items, irrespective of prices, were identified as follows:

Desk-top Microcomputer

- Popular operating system suitable for a wide range of software, (MS DOS).
- Communications software availability.
- 250 kbytes of Random Access Memory with provision for expansion.
- Twin floppy disk drives with a 360 kbytes storage capacity each.
- High resolution monitor.
- Standard RS232 serial and parallel I/O ports.
- Manufactured by a reliable company providing long-term support.

The 'Pocket' Computer

- Relatively robust, ideally shock and waterproof.
- Small and light for portability.
- Battery powered with data and programme power back-up when not in use.
- Standard RS232 serial I/O port.
- 22 kbytes of Random Access Memory.
- Standard computer programme language availability (such as BASIC) with provision for data transmission operations.
- Display one line of 26 characters.
- Manufactured by a reliable company with good documentation and support.

The Printer

- Provide 80 character printing width.
- Accept continuous paper as well as A4 sheets.
- Capable of drawing graphs.
- 80 cps average printing speed.
- Compatible with a wide variety of makes and models of microcomputers.

The Modems

- Full duplex data transmission.
- 300 bps transmission speed.
- Approved by the telecommunication services.

Floppy Disks, and Cables

- Double sided, double density, soft sectored floppies.
- Floppies and cables of reliable quality. (Cheap disks are a false economy.)

THE CASE STUDY

Farm Description

The system was applied to a tank fish hatchery which was producing fingerlings for restocking other fish farms. Fish grading was practiced, and growth sampling was feasible on a weekly basis. A dry pelletised fully balanced nutritional ration was provided to the fish; feeding rates and feeding frequencies varied. The water flow on the farm was evenly regulated throughout the year by a water dam which acted as a buffer and a constant water level/volume was maintained throughout the year in all tanks.

Field Data Capture

The SHARP pocket computer 1500A was very small and could be carried around the farm without difficulty. Protected in a suitable transparent plastic case it has been used as a data input terminal on site and had the additional ability to transmit this data to a desk top microcomputer. Programmed in BASIC language, it accepted fish-farm data input daily and held it in Random Access Memory for a maximum period of one week during which the memory contents were safe even when the machine was switched off. Some data might be entered once a week according to the farm's data collection schedule, and up to 12 different sources of raw data (i.e. tanks or groups of them) could be distinguished.

Data was entered in response to prompts appearing on the small screen. The fish farmer entered first the current day, specified whether it was a daily input or a weekly input, the tank number, then selected the item he wished and typed in the data. Amendments of data figures could be made very simply by repeating the data input procedure.

The Weekly data items accepted included:

- Fish sex (% female)
- Sample weight (Nos/lb)
- Weekly food amount (kgr)
- Daily feed rate used (decimal)
- Feeding method/freq. (text input up to 16 chrs.)
- Food type and size (text input up to 16 chrs.)
- Food quality (energy %).

The Daily data items accepted were:

- Nos of fish dead
- Total dead weight (lbs)
- Transfers IN (Nos)
- Transfers OUT (Nos)
- Size of fish transferred IN (Nos/lb)
- Size of fish transferred OUT (Nos/lb)
- Water temperature (C)
- Water pH
- Dissolved Oxygen, Inlet (morning) (% sat)
- Dissolved Oxygen, Outlet (morning) (% sat)
- Dissolved Oxygen, Inlet (afternoon) (% sat)
- Dissolved Oxygen, Outlet (afternoon) (% sat)
- Oxygenation hours
- Water flow (gal/min)
- Diseases/handling (text input up to 16 chrs.)
- Other conditions (text input up to 16 chrs.)

The units shown were those used in practice by the fish farmer and the data system complied with his preferences.

Data Transmission

Transmitting the data to a desk top microcomputer at a selected location, used as a 'base', formed the second function of the SHARP PC and was made available through its RS232 serial Input/Output port. A SHARP interface was used, which was a separate 'box' slotting into the computer and had its own rechargeable batteries. It provided both an RS232 serial and a parallel port. The data transmission could either be direct, e.g. to a printer or to the microcomputer, when the latter was on the farm office's desk, or long distance/indirect, over the telephone network, to a microcomputer located at a central office. Data was typed into the system once and could be used for either or both of these purposes. In this project an IBM PC desk top microcomputer has been used, with two disk drives, 256k RAM and IBM communications software. The machine had also to be fitted with an Asynchronous Communications Adaptor.

When each week's data was completed, the SHARP was instructed to perform calculations, such as the average temperature or the weighted average of fish sizes transferred in or out of the tank, in order to prepare weekly data for transmission. The communications hardware and software were then set-up and data transmission could take place.

When data transmission by direct connection took place, the pocket computer was connected to the interface. The RS232 serial port was then linked to the RS232 serial port of the Asynchronous Communications Adaptor on the IBM PC via a gender changer.

When both cable and equipment have connectors with the same gender a Gender Changer/Line Switching device is necessary to give the cables the mating pairs needed to mate the equipment.

The communications software was then run, (Asynchronous Communications Support) on the IBM PC occupying the disk drive 'A', and a target diskette, to receive the data, was placed in the other drive 'B'. The system was then ready for the SHARP to transmit the data.

For data transmission by long distance/indirect connection, the SHARP was linked to its interface as before but the RS232 serial port of the latter was now directly connected to a V21 300 bps modem (INMAC Micro Modem). The modem's plug replaced that of the telephone's in the wall socket and the telephone plugged directly into the modem's equivalent socket.

At the other end - at the microcomputer base - another modem of the same type was also in operation. It interfaced with the telephone in the same manner and was connected also to the RS232 serial port of the Asynchronous Communications Adaptor on the IBM PC. The communications software was set-up normally on the PC and the target disk was put in drive 'B' as usual. The final step was for the operator at the 'Sharp' end to dial the operator at base. When the telephone link was established, both operators depressed the 'data' buttons on their modems and replaced the telephone receiver. As soon as the SHARP was instructed the data travelled via the telephone network to the IBM PC at the distant base and on to the target diskette.

However, this procedure presupposes a good telephone network and problems of data corruption may occur in cases of very long distances. Obviously, for a long distance data transmission two operators must be available at the same time, one at each end when cheap modems such as these are used. This is not necessary where more sophisticated modems (auto-dial, auto-answer) are in use which may replace the operator at the base and undertake all the functions needed to 'wake' the microcomputer.

'Sharp' Data Printing

The data may be printed directly from the SHARP and stored away as hard copies. Whenever long distance, automatic transmission is impossible, the hard copies might form the intermediate medium for data input into the desk-top micro. To obtain a printout the SHARP interface with the pocket computer slotted into it should be connected to a printer (any common dot matrix printer of the EPSON range would do). However, the interface should now be connected to the printer via its parallel port.

Data Import into a Lotus 1-2-3 Worksheet

LOTUS 1-2-3 software package (spreadsheet, graphics, database) was used on the IBM PC to process and store data. With the system used data from the SHARP was received and stored on the 'target' floppy disk and the first step was to introduce this transmitted data into a LOTUS worksheet. The data was stored on the 'target' disk in a 'print' file with the ASCII format. This file appeared in the diskette's file directory with the extension '.PRN' to its name. ASCII/'print' files can easily be imported into 1-2-3 worksheets, and in this case a standard worksheet had been customised to undertake the data processing.

Manual Data Input in the Worksheet

The worksheet can be used simultaneously for both manual and automatic data input. By 'automatic' is meant data coming in directly from a field portable device via a clearly defined communications procedure involving specific hardware and software. So, even in cases where a field data capture device is not used and data is recorded on paper sheets, the value of LOTUS 1-2-3 can still be exploited if a manual data entry is used.

Each time a new worksheet file is to be initiated to represent a 'fresh' data source (e.g. a different tank), the general file must accept the initial 'set-up' information about the new fish stock manually. The set-up information includes:

- Fish species reared,
- Identification number of the data source (tank),
- Starting date of production,
- Opening number of fish stocked at the first day of the production cycle,
- Initial biomass of the stocked fish,
- Water volume in the data source (tank).

The Customised LOTUS Worksheet

In this standard worksheet layout, the columns were occupied by the data items, which were therefore displayed across the worksheet from left to right. Data 'time' increments increased from top to bottom by *weekly intervals*. The number of rows/ weekly intervals depended on the duration of the production cycle. One data source, e.g. a tank, and one production cycle were represented in each worksheet file. The worksheet was designed to perform calculations on the imported data automatically and to produce additional data and information (output) as well as to provide instantly generated graphics. This was achieved by the use of LOTUS 'macro' commands which consisted of a series of keystrokes that the worksheet executed automatically as well as by the creation, in advance, of graph formats connected to the data held by the worksheet.

However, some difficulties were encountered when deciding the data calculations to be carried out by the system. These were due to the complexity of the fish farm operations.

PITFALLS IN DATA RECORDS DUE TO SOME COMMON PROBLEMS OF FISH STOCK CONTROL

Accounting for Mortalities

Natural mortalities are considered to be losses due to natural deaths, predation, poaching, escapes, stress etc. In tank fish farming systems accurate food provision adjustments (expressed by the daily feed rate) are possible given the *ability to record mortalities in every day practice*. It is impossible to evaluate accurately production efficiency, say, in terms of food (FCR), unless the precise number of fish that exists in the tank at anytime during the cycle is known. So, by consistent weekly records of fish sample average weights, transfers of fish in/out of the tank, and weekly mortalities in terms of their numbers and the corresponding biomass, the food conversion ratio (FCR figure) does eventually express the conversion efficiency of the healthy fish stock accurately each time. However, the observed mortalities sometimes may represent only a fraction of the actual ones caused by unobserved reasons (herons, escapes). Fish mortalities form part of the tank's production which is wasted. This produce provides no benefit but should not be disregarded theoretically from the production/food conversion efficiency calculations, because no-one really knows how much input was consumed by the wasted fish, and this extra burden is carried by the healthy stock thus worsening their apparent performance in terms of FCR. When observations are inaccurate, and since the average size of the dead fish is known only for the observed mortalities, the calculations of growth do not account fully for this "wasted product".

The same problems must be stressed for the pond fish farming systems as well. A fish pond is a difficult production unit to control in detail. We cannot calculate precisely the total number of the fish population at any point during the production cycle because it is impossible to know the exact number of the fish dying and sinking to the pond's bottom and those which fall victims of predatory birds each day. Because of our inability to account correctly for the numbers of the 'healthy' stock and those of mortalities, the FCR figure which may be calculated by fish sampling does not express the correct food conversion efficiency of the surviving fish population. In fact it may show a worse status for the stock. On the other hand, since the precise number of fish in a given pond is unknown, and moreover, it is very difficult to obtain frequent, accurate and unbiased fish weight samples, the food provision policy adjustments are made by best possible guesses. Inevitably, some daily input/ food losses may occur and build up during the production cycle.

However, the effect upon management practices and the degree of distortion introduced into the records by this relative unaccountability of mortalities is not detrimentally serious. Mortality rates are higher when the fish are still small hence the proportion of food provided per fish is also very small giving a small amount of food waste through mortalities. As the fish grow their numbers are reduced due to mortalities but at a decreasing rate and even if a farmer is misled and overfeeds them he does so at a rate which also decreases. When the fish are large, the mortality rate is low thus, the food amount which may be fed in excess is still not much.

The 'Transfers' Problem

Fish are transferred *out* after grading to bring uniform sizes together, or to fulfil a customer's specific order, and are therefore not taken at random. The sampled or projected average size figure of the fish for the end of a period (week) is affected by such transfers when a number of individuals from a certain size group is removed.

When the removed fish are of the bigger sizes the sampled average size shows an artificially bad status of fish growth, especially when a lot of big fish are taken out. When smaller fish are removed from the tank the effect on the average sample size figure is opposite, especially when a large number of small fish are taken out, and may end up with a misleading result showing fast growth.

Transfers of fish *into* a tank also happen after grading, when fish of uniform sizes are brought together. Therefore, they tend to conform with the existing average size of fish in the tank. Transfers of fish in a pond often happen at the very beginning of the production cycle when the pond is being stocked and consist of many small fish. Again these fish transfers into the pond do not produce any surprises because the fish are subjected at an early stage of their growth to the particular pond's environment and they match with the existing average weight already in the pond.

When grading, fish may be transferred in and out of a tank simultaneously, which enhances the *artificial "transfers' effect" upon the average weight samples.*

Fish transferred in, generally, although they may comply with the existing average size of the fish already in the tank/pond, cannot be regarded as real production of it. They represent extra biomass which is picked up by the fish weight samples but should not be allowed to distort the data records or the calculations of the final production cycle results. On the other hand, transfers out are the real production of a particular tank/pond. Therefore, the fish removals for subsequent sale from a unit must be considered together with those removals which redistribute fish into the other units on farm and taken into the calculations for the unit which produced them. The total biomass produced during a time interval must be regarded as the sum of all biomasses transferred out from the particular unit reduced by the sum of the biomasses which have been 'donated' to it within that time interval.

THE WORKSHEET OUTPUT

Data Calculations (weekly)

The formulae which have been built into the customised LOTUS 1-2-3 worksheet were designed to avoid most of the distortion introduced by the stock management operations and to give accurate information on the growth situation of the fish. Some of these calculations may not be immediately obvious and the interested reader may need to cross reference them carefully, or even work out a simple numerical example, in order to obtain the right impression. A list of the weekly data output and its calculation follows:

Opening fish N^{o}
= Previous week's closing fish N^{o}.

Closing fish N^{o}
= Opening fish N^{o} + Transfers IN - Mortalities - Transfers OUT.

Opening Average fish size
= Opening total biomass/Opening fish N^{o}.
This calculation is made for the first week of the production cycle only. For all successive weeks the following is used:
= Previous week's closing average fish size.

Average Conversion Ratio (apparent) in decimal form, representing the weight units of food used per weight unit of growth.
= Total food provided/true biomass gain.

Actual average daily feed rate used, as opposed to the standard daily feed rate recommended by the food manufacturer's tables, (in decimal form)
= (Total food provided/Opening total biomass) / 7.

Average weight gain
= True biomass gain/(Opening fish Nos - mortalities).

Opening total biomass
= Previous week's Closing total biomass.

Biomass increase due to fish transferred IN
= Nos of fish transferred IN* their weighted average size.

Biomass decrease due to fish transferred OUT
= Nos of fish transferred OUT* their weighted average size.

Closing total biomass
= Closing fish Nos* Closing average fish size.

True biomass gain
= Closing biomass - Opening biomass - Biomass transferred IN + Biomass transferred OUT.

Stocking density (Nos)
= Opening fish Nos/Tank water volume.

Stocking density (opening Biomass)
= Opening total biomass/Tank water volume.

Worksheet Report

The last part of the worksheet served as a report of the overall production. It could be printed separately, and showed the current overall results of the production cycle. Some of its calculations were unavoidably affected by either the fish transfers or the imprecise mortality observations, and due regard should be paid to such distortions when the summarised results were interpreted. The report incorporated the items shown below with their calculation:

End biomass produced
= SUM (Biomass decrease due to transfers out).

End fish Number produced
= SUM (Fish transferred out).

End actual average fish size
= End biomass/End fish No produced.

Duration of production (Nos of weeks)
= MAX (Week number).

True end biomass gain
= SUM (true biomass gains).

Apparent end biomass gain[3]
= End biomass - Initial fish biomass.

Apparent end average fish weight gain[3]
= Apparent end biomass gain/End fish No produced.

Apparent average growth per day per fish[3]
= Actual end average fish weight gain/ (Duration of production in weeks * 7).

Total food fed
= SUM (Total week food).

FCR overall production (apparent)[3]
= Total food fed/Actual end biomass gain.

Total mortalities (observed mortality Nos)
= SUM (Weekly mortalities).

Real Natural Mortality Rate
= (Initial fish No stocked - SUM (Transfers out)) / (Initial fish No stocked + SUM (Transfers in)).

Graphs in the Customised Worksheet

The procedure to create a graph with 1-2-3 may seem complicated to the novice or in fact be a nuisance to the very busy user. In the customised worksheet used here, graphs were inbuilt for 'instant' easy use. Their formats were present

[3]A Degree of distortion is introduced to these figures due to the aggregate effect of unaccounted mortalities and fish transfers.

even when the worksheet contained no data and they started to take shape as the figures accumulated. The data figures graphed were:

- Total Week's Food,
- Actual Average Daily Feed Rate,
- Average Week Weight Gain,
- Closing Average Fish Size,
- Week Closing Total Biomass,
- Average Week Temperature - Morning -,
- Stocking Density (Biomass/m^3 or ft^3),
- Dissolved Oxygen,
- Water pH,
- Actual & Standard Av. Daily Feed Rate.

CONCLUSIONS

Recognising the needs for every day data collection on the fish farms and the difficulties that it creates to farmers, a computerised data recording system was developed in the hope of reducing the anxiety that data collection and storage creates and to encourage systematic record keeping.

A system which accepted a minimum amount of physical data items in order to facilitate an effective production and stock control and which was useful in providing strategic data for planning was tested. Data was input into the system once, on site, and all subsequent tasks of its handling had been fully automated.[4] Though it might seem, because of the example given, that this data system is relevant to a particular farm situation only, its simple design and standard software require only minor adjustments for use on any other different fish farming system. The fish production systems' main difference relies on the ability or not to grade and sample the fish frequently and with accuracy. For example, in tank culture systems growth and mortality control is tight and accurate, whereas in pond systems only short term predictions rather than observations are available.

Be they best possible guesses or accurate samples, however, data has to be recorded and 'saved' in a 'data bank' in order to support efficient decisions at a later stage, and the files created by the computer provide the most convenient data store. Many data files can be recorded on a single diskette, and so perhaps the physical data of all the fish farm systems data units may be found on a few "floppies".

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