World Academy of Science, Engineering and Technology
International Journal of Animal and Veterinary Sciences
Vol:7, No:3, 2013

International Science Index, Animal and Veterinary Sciences Vol:7, No:3, 2013 waset.org/Publication/11220

Minimizing Fish-feed Loss due to Sea Currents: An Economic Methodology

V. Vassiliou, M. Charalambides, and M. Menicou

Abstract**—**Fish-feed is a major cost component of operating expenses for any aquaculture farm. Due to soaring prices of fish-feed ingredients, the need for better feeding schedule management has become imperative. On such factor that influences the utilization rate of fish-feed are sea currents. Up to now, practical monitoring of fish-feed loss due to sea currents is not exercised. This paper gives a description of an economic methodology that aims at quantifying the amount of fish-feed lost due to sea currents and draws on data from a Mediterranean aquaculture farm to formulate the associated model.

Keywords**—**Aquaculture, economic model, fish-feed loss, sea currents.

I. INTRODUCTION

FISH-feed is perhaps the most crucial cost factor for any aquaculture company's operating expenses. It is generally accepted that fish-feed cost represents from 50 to 70% of total aquaculture production costs [1],[2]. As the ingredients of fish-feed soar caused by the rise of their respective commodities' value, (typical ingredients are soybean, corn, fishmeal, fish oil, rice and wheat) [1] so does its impact on the operating costs.

Apart from the aspect of economic loss, if large quantities of uneaten fish-feed sink to the bottom beneath the cages they may also have an unfavorable impact on the marine environment. Water quality will be affected, fish stock will be threatened and deleterious impacts will be created on the surrounding marine environment. This is because oxygen depletions may occur due to decomposition of accumulated waste materials in addition to fish feces.

As a result, aquaculture companies try to balance their feeding strategies to ensure maximum utilization of fish-feed, thus minimizing loss. Feeding too little results in low fish-feed cost but also less growth [3]. Conversely, feeding too much in order to achieve greater growth leads to feed wastage, a pure economic loss, and of course greater waste output [3],[4].

Maximizing fish-feed utilization comes as result of an iterative procedure with the use of formal and empirical ways. Formal ways come in the form of theoretical biological models [4], economical models or of feeding charts provided by feed manufacturers or found in various publications [3]. Empirical ways have the form of empirical biological models based on specific case studies (farm, species reared, environmental parameters etc.) see [5], and as [3] states, common sense, the so-called human heuristic.

Yet the simplest factor that a producer can monitor in order to minimize the fish-feed loss, is the prevailing environmental conditions at the farm site at the time of feeding. While prevailing environmental conditions in respect to aquaculture enclose a number of parameters such as wind, waves, currents, water temperature, oxygen levels etc., a producer can narrow those down to just about two groups, (a) winds and waves and (b) sea currents. Even though the former is easy to understand how it affects the fish-feed loss, the latter is not as obvious. It is possible for strong currents to exist without the coexistence of high waves and/or strong winds. Currents, in terms of depth of occurrence, speed and direction, even though are necessary for adequate water exchange and waste dispersion, need to be within defined values. Strong currents will apparently drift the feed pellets away from the cage before the fish have time to eat. This eliminates the adequate opportunity, in terms of time, for fish to consume the determined ration and achieve their growth potential [3].

Consequently, this paper presents a straightforward methodology for quantifying how much fish-feed is lost due to sea currents. All associated input parameters are explained and their nature is described. Note that the terms aquaculture sites and fish farms are going to be used interchangeably in this paper.

II. LITERATURE REVIEW

In aquaculture industry, the amount of fish-feed lost is addressed as part of pollutants dispersion models generally develop to monitor organic waste and their impact on the marine environment, which include fish-feces [6], and antibiotics [7].

One such commercial model is called MOM which stands for Modelling - Ongrowing fish farms-Monitoring and it is used to adjust the local environmental impact of marine fish farms [8]. The MOM model is composed out of five sub-models, the most important of which is the dispersion sub-model. This simulates dispersion and sedimentation rates of excess feed and fecal pellets [8]. In particular, as [8] states, from the current variability, and the estimated sinking time for the organic waste, the model calculates how waste from a single net cage spreads over the bottom.

Another well-known model is the DEPOMOD. This commercial model was developed in Scotland to predict organic deposition under finfish aquaculture sites [9]. It is a computer particle tracking model and it is used for assessing

Vassiliou Vassos, Charalambides Marios and Menicou Michalis are with Frederick Research Centre, 1303 Nicosia, Cyprus (e-mail: eng.vv@fit.ac.cy; bus.cm@fit.ac.cy; eng.mm@fit.ac.cy).

International Science Index, Animal and Veterinary Sciences Vol:7, No:3, 2013 waset.org/Publication/11220

the potential impact of a farm throughout a growing cycle, or if the biomass consent is increased [10].

The MERAMOD model is a conversion of the DEPOMOD model coupled with particle tracking and benthic response modules. This model is of special interest since it was validated in the Mediterranean Sea for predicting waste solids flux and benthic impacts of sea bream (Sparus aurata L.) and sea bass (Dicentrarchus labrax L.) aquaculture sites [11].

All of these models have as their main purpose the quantification of aquaculture's impact on the environment and as [11] reports, for assessing the effect of mariculture discharges with the overall aim to aid the environmental management and regulation.

The following methodology is simpler, more straightforward in nature, and focuses only on the fish-feed loss, avoiding terms such as dispersion coefficients, settling rates and current shear and turbulence, terms that require sophisticated equipment and laboratory tests to validate their results.

III. CASE STUDY FARM

This paper examines fish-feed loss for an aquaculture company established in Cyprus, in the south Mediterranean. The farm is located at the north side of the country "behind" the Akrotiri Peninsula that acts as a physical barrier and protects the farm from extreme weather conditions.

There are 18 cages arranged in two rows of nine floating cages each. The cages are moored on the seabed, which is around 40 m deep, based on the surface grid arrays system. The mooring system is composed of cement block anchors, shackles, chains, lines, ropes, rope rings and buoys (see [12] for a more detailed description). The farm has a rectangular shape and it is oriented with an angle in respect to the coastline. This is done to better protect the farm since its narrower side faces the predominate winds that blow from the southwest.

The reared species are seabream (Dicentrarchus labrax) and seabass (Sparus aurata). The following Fig. 1 illustrates the farm's distance from shore, its orientation and the cage arrangement.

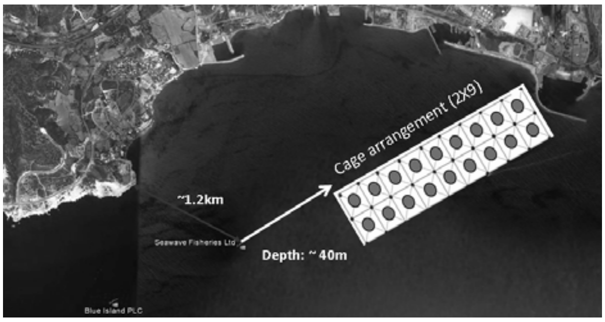

Fig. 1 Location, orientation and cage arrangement

IV. PRODUCTION PROCESS

The description of the production process and its composing procedures is essential for understanding the inherent parameters that affect the economic methodology. These are easily identified, categorized and modeled through another research project performed by the same authors and are described in [5] and [13].

A. Production Cycle

Fish production cycle is found to be on average around 15 months based on the data under study which is in accordance with other similar studies [15]. At the end of the cycle the final output (reared fish) reaches the desired weight level. This level is in between 330-450 gr to which the best price is captured. More than 500 gr the fish is considered too big to be sold thus a lower price is achieved, similarly, less than 330 gr the fish is consider not big enough.

B. Initial Fingerling Placement

The time of fingerlings' (juvenile fish) initial placement, plays a significant role in terms of production output. As shown in the following Fig. 2, fish growth at the beginning is sluggish when fingerlings are placed during the winter season compared to the summer season at which there is an almost linear growth pattern. Additionally, the maximum fish mass for summer fingerling placement is, on average, greater of that of winter placement.

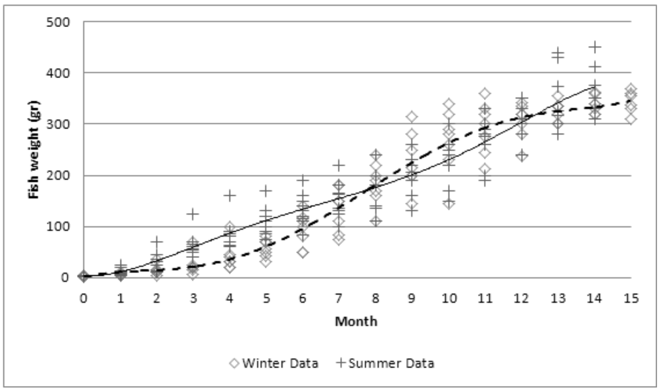

Fig. 2 Growth rate per season

C. Growth Phases

The entire production process can be categorized into five discrete phases [5] based on the average fish weight. This is extracted from the feeding charts that the fish-feed producer provides for the specific species. Phases are denoted with the Greek letter Φ and the index i which ranges from 1-5, indicating the phase. In detail, Φ_1: 3-10 gr; Φ_2: 10-40 gr; Φ_3: 40-100 gr; Φ_4: 100-250 gr; and Φ_5: 250-350 gr.

D. Fish-Feed Type

Based on the growth phase – more specifically the average fish weight - and the water temperature (denoted as T), the fish-feed producer suggests a feeding rate or ration size expressed in percentage of fish weight. For example, for Φ_1 corresponding to an average fish mass of 3-10 gr and water temperature (T) of 17 degrees Celsius the producer suggests an index of 2.4 % of the average fish mass. Note that as [4] states optimum feeding rates ensure the best growth.

International Science Index, Animal and Veterinary Sciences Vol:7, No:3, 2013 waset.org/Publication/11220

Fish-feed type is denoted as D with an index j ranging from 1-6 (the number 5 is excluded). Thus, for each case there are D_1, D_2, D_3, D_4, and D_6 each of which has a different cost expressed in euros per kg. More importantly, each fish-feed type comes in the form of pellets with a different size. The pellets start with a size of 1.8 mm for type D_1 fed to juvenile fish weighting from 3 to 10 gr, and reaching up to 6 mm fed to adult fish, weighting more than 500 gr.

Emphasis must be given to the fact that the feeding rates are used as yardsticks for how much the fish must be feed. In the case study farm these tables work more as the upper limit of fish-feed spread. This is not strange since it is a common practice in aquaculture in general, as stated in [3].

E. Feeding Practices

Feeding occurs every day – or almost every day – depending significantly on the weather conditions, among other parameters. Optimal feeding frequencies, as this is called, are considered a grey area in aquaculture, as reported by [4]. In the case study farm as a rule of thumb feeding is performed only once per day but the amount of fish-feed is dispensed in two or three rounds depending on the growth phase, in order to enable the cultivated population to eat as much as possible.

Workboats perform the feeding and fish-feed is spread with the help of blowers powered with portable batteries. The amount of fish-feed is determined through the use of the feeding tables, average fish mass (growth phase, Φ) and water temperature as explained in paragraphs C and D.

In some cases at the end of the production cycle, the fish population may be fed fewer times than they normally do, in order to burn any excess fat. How may times depend on the fat level determined through fish sampling and experience. Generally speaking, two before days before harvesting the fish-population is fasted.

The most common reason for interruption of the feeding schedule is usually high waves especially when they coexist with strong winds that prohibit the safe approach of feeding workboats near the cages. However, these can be easily monitored through observation. In particular, since the farm is located relatively close to shore, as shown in Fig.1, the wind profile on-site is *a-priori* extrapolated from onshore weather stations and it is known to have only minor deviations. Historical data ranging from 1996 to 2010, recorded from the Cyprus Meteorological Service, indicate that the highest winds speeds (gust) occur from November to February. The direction of these winds is from the southwest in between 195 and 225^{o}, which explains the orientation of the farm, as shown in Fig. 1.

Sea-currents also have an effect on the feeding practices. In contrast to wave heights that can be seen from shore, sea currents are only known to be of low magnitude due the shielded location of the farm, *behind* the Akrotiri Peninsula. Yet the farm's personnel always observe the currents on-site before feeding in order to adjust the position of the feeding workboat. Note that even though sea currents are necessary for adequate water exchange and waste dispersion, they must be within appropriate limits to remain beneficial. More importantly though is that there are not any historical data that illustrate the pattern and profile of the sea currents for the location of the farm.

F. Mortality/ Escapees

As expressed in [5], during the various growth phases, fish population may be reduced due to various reasons, causing their mortality. Similarly, although of lower magnitude since the nets are inspected daily, fish can also escape from the cage which also adds to the reduction of the fish population.

V. ECONOMIC METHODOLOGY

The economic methodology set-up for quantifying in monetary terms the cost of uneaten fish-feed pellets starts by developing a model where the entire production procedure is represented.

A. Quantifying Fish-feed

The first step is selecting a time horizon of 15 months equal to the production cycle. This is divided into seasons and then into weeks. As a result, for a time horizon of 15 months there are 61 weeks and five seasons with the first and the fifth season being the same.

Initial fingerling population is the first key input variable entered. In addition, the average fish mass of this initial population is also recorded. Knowing these two variables, the exact number of juvenile fish placed into the cage and there average mass, the final reared kg can be calculated after the 15-month cycle by factoring in all other associated parameters.

The existence of growth rate variations is response to the initial fingerlings placement suggests that four identical sub-models are created. Each model represents the initial placement season. The growth rate is governed by the equation that gives the fish mass as a function of time, as depicted in Fig. 2. These equations are extracted through graph best fit in empirical data taken from the case study farm. They are of a polynomial type of the 6th degree.

The type of fish-feed is then included. As discussed in paragraphs C and D of section III, the type of fish-feed is taken from feeding tables given by the fish-feed producer and are a function of the fish's growth phase and temperature. The growth phases are calculated through the growth equations, while the season's average temperature is given by the farm's production manager. Finally, based on the type of fish-feed the cost is then recorded. The cost is in the form of euro per kg of fish-feed.

Next the feeding rate is selected which is set again by the fish-feed producer. The growth equations provide the average fish mass depending on the month of the growth cycle.

Mortality is also a part of the economic methodology. In particular, the associated model (and sub-models) takes into account the mortality at each growth phase. Mortality is given per season, thus, here end-of-the season assumption is made meaning that the starting population is reduced by the specific mortality rate at the final week of each season.

The next step is to include a coefficient that represents the number of times that weather conditions prevent feeding schedule. This coefficient is given as a percentage and its magnitude is well recorded but can vary each year. It's titled feeding frequency. Note that this coefficient represents the situation of high waves and/or winds.

Finally, through the multiplication of the average fish mass with the (initial) population, the feeding rate, the feeding frequency, the daily fish-feed quantity spread is calculated. Nevertheless, since the model is divided in weeks this result is multiplied by seven.

It is important to signify that some of these variables are of stochastic nature best represented as distributions. To define the probability distributions that describe the stochastic variables the model relies either on extensive analysis of historical data, using @Risk software or on company experts' judgments. The following Table I depicts all variables and their nature.

TABLE I
INPUT VARIABLES

Variable	Symbol	Deterministic - Stochastic
Production Cycle	N	Deterministic
Fingerlings quantity	P	Stochastic [in units]
Average mass of P	m_P	Stochastic [in gr]
Average water temperature	T	Deterministic
Average fish mass	m	Deterministic [in gr]
Fish-feed type	D	NA
Fish-feed cost	C_D	Deterministic [in €/ kg]
Mortality	M	Stochastic [as %]
Feeding rate	f_R	Deterministic [as %]
Feeding frequency due to winds/waves	f_{ww}	Deterministic [as %]

4 Seasons governed by 4 different growth equations Fish mass = f(time)

B. Sea Currents

In general, the Cyprus Oceanography Center (COC) monitors sea currents of the coastal and open sea areas of Cyprus with the Cyprus Coastal Ocean Forecasting and Observing System (CYCOFOS) [16]. The COC delivers daily current profiles as well as five-day forecast for surface currents and currents at 30 m depth.

However, currents are location specific phenomena affected by various parameters near the area of investigation. Thus, in order to extract reliable results *in situ* measurements are required.

Consequently, the methodology takes into account current measurements that were obtained through the deployment of a specialized instrument from Aanderaa Company, which is a Doppler current profiler. The instrument is called RDCP600 and it belongs to the category of ADCPs, which stands for Acoustic Doppler Current Profilers. In particular the RDCP is a medium range, 600 kHz, self-recording Doppler Current Profiler (RDCP) [13], that was configured to deal with several columns (profiles) simultaneously for optimum flexibility, as shown in Fig. 3.

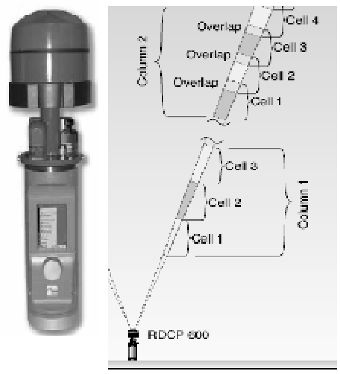

Fig. 3 The RDCP600

The instrument was anchored at one of the first cage's cement blocks, as shown in Fig. 4.

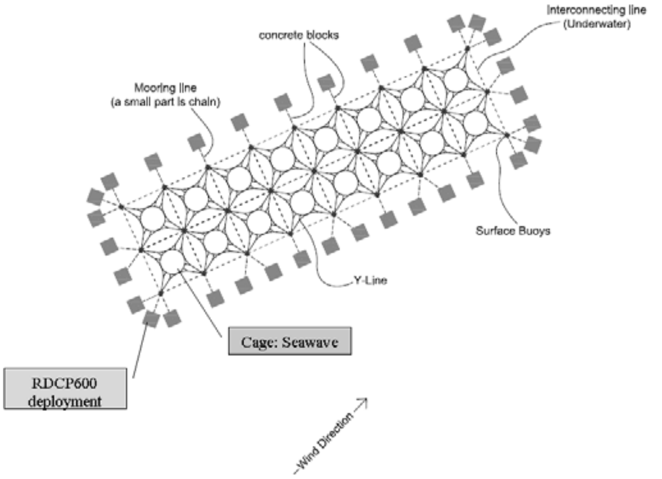

Fig. 4 Top-view of farm and deployment location of RDCP600

With the use of the dedicated software accompanying the instrument, RDCP Studio, we were able to process the recorded data and extract the current profile at the area of investigation. In particular, we were able to determine the vertical and horizontal speeds and direction at each depth. Fig.5 illustrates the minimum, maximum and average horizontal current speed in cm per second for each cell. The cells represent measurement space and are instrument referred meaning that the zero cell corresponds to the sea's surface whereas the 40th cell corresponds to the bottom of sea, where the instrument is anchored. Note that each cell covers an area of 2 m of the water column above the instrument and that cells have a 50% overlap with each other.

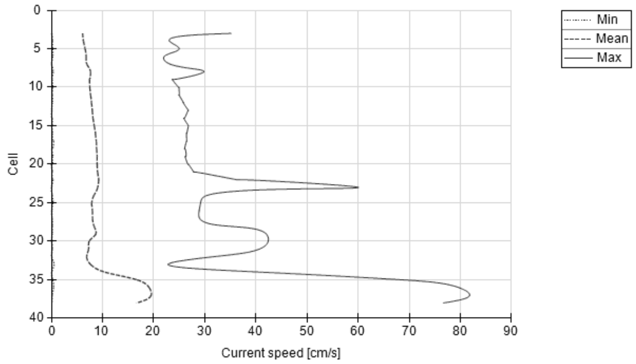

Fig. 5 Min. mean and max. current speeds per cell

C. Integrating Current Profiles into the Economic Methodology

Current profiles extent for the entire water column above RDCP600, yet only the profile at the top 12 m is necessary for the economic methodology and the respective model. This is because the net-pen extents from the surface up to -12 m, thus theoretically the fish population can consume fish-feed pellets up to that depth. Note that despite the tension weights that exist to hold the net-pen in place (refer to Fig. 6), strong currents can deform the tubal shape of the net-pen, towards their direction, thus minimizing the space within fish can consume.

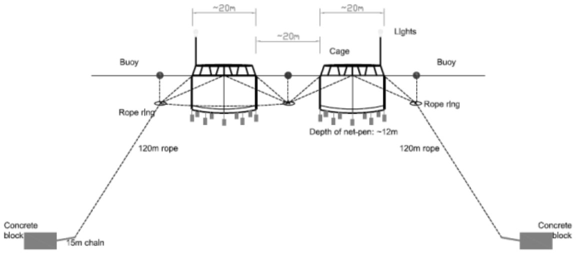

Fig. 6 Side-view of aquaculture cages

In practice, the analysis takes into account the current profile at 2-4 m of depth at which empirically this is where the most fish-feed is eaten.

Associating the effects of sea currents with the fish-feed as this is calculated in section A, is with the use of expert opinion and real data. There is a lot of anecdotal knowledge, in the form of percentage range, amongst the personnel of the case study farm – this includes divers and boat personnel – which can be associated to how much fish-feed is approximately lost in discrete current magnitudes. For example, at low magnitude currents, almost 99% of the fish-feed is consumed. In contrast, in mid and high magnitude currents this percentage is lower hence the lost percentage gets higher. With actual current profiles in place, it is possible to identify what are lower, average and high magnitude currents by segmenting them in 3 or 5 meaningful discrete groups. These groups are going to be grouped again in seasons in order to have a similar time period analysis as the rest of the economic factors. From then on associating each fish-feed loss percentage with a specific group of sea current profiles will provide guiding points on a two-axis graph.

The next step is to best-fit the type of graph that will explain how much fish-feed is expected to be lost at each specific sea current profile. This relation could be linear or not depending on the data. At each stage and depending on the recorded sea current data the model's user can consult the two-axis graph and interpolate what would be the anticipated fish-feed loss as a result of sea currents.

Consequently, the economic methodology and the respective model will be augmented with another factor representing the overall and per season loss of fish-feed caused by sea currents. The following Table II depicts the new parameter in place.

TABLE II
INPUT VARIABLES

Variable	Symbol	Deterministic - Stochastic
Loss due currents	f_c	Deterministic

VI. UTILIZING THE ECONOMIC METHODOLOGY

The proposed methodology is intended to be utilized as an *ex-ante* analysis of how much fish-feed was lost at each production cycle for each cage. It utilizes theoretical and empirical evidence to reach at the desired conclusion.

Its goal is to firstly quantify the fish-feed lost due to sea currents and then, by continuously fine-tuning the methodology's variables and the respective model's assumptions, try to minimize it.

The proposed criterion to be used for this action is a ratio called the Feeding Conversion Ratio (FCR). The FCR represents the amount, in kg, of fish-feed spread during the entire production cycle over the gained total fish mass, also expressed in kg. Obviously, inherently, the fish-feed spread is assumed to be the one consumed, yet in practice the ratio is calculated without taking into account the fish-feed loss caused by currents but only due to other, more "obvious" variables such as waves and wind, temperature etc,

Typically, seabream and seabass cultivated in the Mediterranean have FCRs of around 2.1 [14]. Nevertheless, other studies for species of the same family indicate a much lower FCR [16].

It is critical to have a fine-tuning period where the growth equations and the recorded fingerlings' average mass are included into the model. Note that the average fingerlings' mass affects the mass at subsequent phases through the growth equations. Since at the beginning the farm does not keep as detailed data as the ones need for the analysis, it could rely on the growth equations having as data only past data. From then on it can keep track of the fish population's mass on a weekly basis thus the growth equations can be replaced.

This proposed methodology helps fill in the gap that exists with respect to the currents' influence on fish-feed loss. The production manager of the respective farm, not only will now have a better view of how much fish-feed is actually utilized but also better manage the feeding schedule. *Ceteris paribus*, the production manager can now make alterations on the feeding schedule based also on the currents' profile and monitor the FCR to see if this has any positive effect. If the bottom line result, i.e. the FCR, is now better than before then he can reschedule accordingly.

VII. LIMITATIONS

The described economic methodology combines theoretical models with empirical data. Such approaches always enclose a degree of uncertainty. Models, although highly powerful, are mere representations of reality full of assumptions and not reality itself. Unless the latter are replaced with actual, real-life evidence and unless this methodology is put into action no reliable conclusions can be drawn.

Moreover, fish-feed loss may occur due to other reasons coexisting with strong currents such as concentrations of dissolved oxygen, ammonia and even non-quantifiable ones such as the quality of the fingerlings and fish social behavior. Validating the methodology's results must come by selectively addressing and monitoring each reason at the time.

VIII. CONCLUSION

This paper presented an approach description of an economic methodology that tries to capture the cost of lost fish-feed caused by high magnitude currents. The methodology utilizes existing theoretical knowledge with real-life data concerning an aquaculture farm in the Mediterranean.

The methodology is relatively straightforward and includes parameters such as water temperature, fish-population mortality rate, fish mass etc. By combining all those parameters and factoring in the inherent personnel knowledge regarding fish-feed loss during high current speeds, its aims at quantifying the loss.

The future use of additional commercial instruments such as feeding cameras (see [17] for a description), besides the RDCP600 current profiler, can help better fine-tune the model and validate the entire approach.

ACKNOWLEDGMENT

This research paper presents the results of the project with the code ΤΕΧΝΟΛΟΓΙΑ/ ΜΗΧΑΝ/ 0609(ΒΙΕ)/ 01, titled: "A smart feed management data tool for Cyprus' offshore aquaculture industry with the aid of a stand-alone renewable energy system", co-funded by the Republic of Cyprus through the Cyprus' Research Promotion Foundation and the European Regional Development Fund of the EU.

REFERENCES

[1] Foster, M., Petrell, R., Ito, M. R., Ward, R., Detection and counting of uneaten food pellets in a sea cage using image analysis, *Aquaculture Engineering*, 14, 1995, pp. 251-269.

[2] Lindsey, P., 2010, *FAO: Fish feed costs to remain high* [Online]. Available at: http://www.seafoodsource.com/newsarticledetail.aspx?id=4294998760 [Accessed: 20 December 2012].

[3] Cho, C.Y., and Bureau, D.P., A review of diet formulation strategies and feeding systems to reduce excretory and feed wastes in aquaculture, *Aquaculture Research*, 32 (Suppl. 1), 2001, pp.349-360.

[4] S.S. de Silva, T.A. Anderson, "Feeding Practices in Aquaculture", in *Fish Nutrition in Aquaculture*, 1st ed, Chapman & Hall London: Springer, 1995, pp.218-227.

[5] Evangelos Bellos, Vrassidas Leopoulos, Michalis Menicou, Marios Charalambides, "Production Planning in the Aquaculture Industry: A Simulation-based Approach", in *Proc. of the 24th Annual European Simulation and Modelling Conference*, Hasselt, 2010.

[6] Perez, O.M., Telfer, T.C., Beveridge, M.C.M. and Ross, L.G., Geographical Information Systems (GIS) as a Simple Tool to Aid Modelling of Particulate Waste Distribution at Marine Fish Cage Sites, *Estuarine, Coastal and Shelf Science*, 54, 2002, pp.761–768.

[7] Tironi, A., Marin, V.H. and Campuzano, F., A Management Tool for Salmon Aquaculture: Integrating Mohid and GIS Applications for Local Waste Management, "Perspectives On Integrated Coastal Zone Management In South America" (Eds.), IST, Press, 2008.

[8] Ervik, A., Hansen P.K, Aure, J., Stigebrandt, A., Johannessen, P., Jahnsen, T., Regulating the local environmental impact of intensive marine fish farming I. The concept of the MOM system (Modelling-Ongrowing fish farms-Monitoring), *Aquaculture*, 158, 1997, pp. 85-94

[9] Canadian Science Advisory Secretariat, Science Advisory Report, 2012/042, Review of DEPOMOD Predictions Versus Observations of Sulfide Concentrations Around Five Salmon Aquaculture Sites in Southwest New Brunswick.

[10] Cromey, J.C., Nickell, D.T., Black, D.K, DEPOMOD—modelling the deposition and biological effects of waste solids from marine cage farms, Aquaculture, Vol. 214, Is. 1–4, 2002, pp. 211–239.

[11] Cromey, J.C., Thetmeyer, H., Lampadariou,N., Black, D.K., Kögeler, J., Karakassis, I., MERAMOD: predicting the deposition and benthic impact of aquaculture in the eastern Mediterranean Sea, *Aquaculture Environment Interactions*, Vol. 2, 2012, pp. 157–176.

[12] Vassiliou, V., Menicou, M., Charalambides, M., DeCew, J. and Tsukrov I., "Cyprus' Offshore Aquaculture Mooring Systems: Current Status and Future Development", *In Proc. Of the International Conference on Biological, Ecological and Environmental Sciences, and Engineering Zurich*, 2012.

[13] Menicou Michalis, Marios Charalambides, and Vassos Vassiliou. "A Profit Optimization Decision Support Tool for the Offshore Aquaculture Industry", In Management and Control of Production and Logistics, pp. 166-171, 2010, *Proceeding of the 5th International Conference on Management and Control of Production and Logistics.*

[14] Beverly A. Wagner and James A., Young, Seabass and seabream farmed in the Mediterranean: swimming against the tide of market orientation, *Supply Chain Management: An International Journal*, Vol. 14, 6, 2009, pp.435–446.

[15] Cyprus Coastal Ocean Forecasting and Observing System, 2012 [internet]
Available at: http://www.oceanography.ucy.ac.cy/cycofos/

[16] Kim, D.H., Lipton D., Choi, J.Y., Analyzing the economic performance of the red sea bream Pagrus major offshore aquaculture production system in Korea, *Fisheries Science*, Vol. 78, Issue 6, pp. 1337-1342, November 2012.

[17] Camera Systems – Aquaculture, AKVA Group
Available at: http://www.akvagroup.com/products/cage-farming-aquaculture/camera-systems/basic-hr-camera

Vassiliou Vassos is a Research Associate at Frederick Research Centre in Cyprus. He holds an MBA from the Cyprus International Institute of Management (CIIM) since 2009 and a Diploma in Mechanical Engineering from the National Technical University of Athens (NTUA) since 2007 with a specialization in Industrial Management. Currently his is a PhD candidate at NTUA at the Sector of Industrial Management and Operational Research at the department of Mechanical Engineering.

Charalambides Marios is a Lecturer of Applied Mathematics in the General Department at Frederick University. He is also an affiliated Research Fellow at Frederick Research Centre (FRC), Cyprus. He holds a PhD in Mathematics (Applied Mathematics), a PhD Minor in Finance and an MA in Mathematics from the University of Wisconsin Madison, in USA. He also holds a BSc in Pure Mathematics from the University of Cyprus.

His research interests are consistent of two components: (a) Basic research that includes numerical analysis of channel flows and geometry of polynomials with special interest to stable polynomials and polynomials with real negative roots. (b) Industrial research that includes optimization methods, risk analysis and structural dynamics. Dr Charalambides has published in leading journals of his field.

Menicou Michalis is an Assistant Professor at the Department of Mechanical Engineering, Frederick University, Cyprus. He is also an affiliated Research Fellow at Frederick Research Centre (FRC), Cyprus. He holds a Ph.D. from the University of Sheffied, UK, an MBA in Industrial Management from Sheffield Hallam University, UK, and an M.Sc.(Research) in Materials, Structures and Systems Engineering from the University of Sheffield, UK.

Over the past few years, he has set up and coordinated more than ten (10) international research projects with partners from Europe and the USA in the field of Industrial Management, application of Renewable Energy Sources Technologies and food sustainability. He is the author of more than thirty scientific papers to referred journals and referred conference.

International Science Index, Animal and Veterinary Sciences Vol:7, No:3, 2013 waset.org/Publication/11220