An economic assessment of current practice and methods to improve feed management of caged finfish in several SE Asia regions

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1. Executive Summary

Intensive sea cage aquaculture is in its infancy in SE Asia although there is still significant production of approximately 130,000 tonnes of mixed tropical species (*Epinephelus sp., Lutjanus sp., Plectropomus sp., Cromileptes sp., Rachycentron sp., Lates sp.,* and others) carried out in small wooden systems that are fed manually. This compares to the industrial farming techniques (large cages and automation) found in Europe, America, Australia and Japan (*Salmo sp., Seriola sp., Pagrus sp., Dicentrarchus sp., and Sparus sp.*)

In order to grow this sector sustainably in SE Asia, the existing sea cage industry needs to under go certain reforms. These include:

- reliable hatchery supply of disease free fingerlings from disease free broodstock
- trait selection programs targeted at key species for domestification
- modernization of the sea grow-out systems (eg; larger more durable cage systems - steel/HDPE plastic)
- feed management technology
- cessation of trash fish use for development of suitable dry pelletised diets
- relocation of cage systems from sub-optimal sites to locations with deeper, better quality water
- greater degree of government and private sector co-operation (e.g. government & private sector sea cage research facilities where long term research can occur into nutrition, feed management, disease control, broodstock control and domestification programs).

These reforms will help this sector to become a significant contributor to the regional economy in an environmentally sustainable manner.

2. Background

Modern cage farming, particularly marine, is at an embryonic stage in SE Asia. Research is in progress on the early life stages, particularly in fry and hatchery technology (Rimmer et al., 1998), however there is still much work to be accomplished on the sea cage grow-out component. The primary aim of this report is to evaluate current farming methods, feeding practices, economic conditions and other aspects of husbandry in several SE Asian locations and to list recommended measures for improvement.

Modern feeds, cage technologies and sensor based feeding systems have proved effective in increasing production efficiency in most of the intensive cage aquaculture industries worldwide. The present paper will discuss the importance of satiation feeding to optimization of production performance and demonstrate the value of this with data from several research programs undertaken in Europe and Japan. An economic evaluation of the benefit of implementing modern feed management technology with existing systems and improved cage technology is also provided.

3. Importance of Feed Management

Feed management is one of the key components of any cage aquaculture operation. It involves the efficient use of the largest single contributor to overall production costs in intensive aquaculture: feed. Manufactured feed often represents 50-70% of operational costs a fact that belies the need to optimize feed management leading to improvements in production efficiency.

For most farmed species feed intake has been found to vary primarily with temperature, day-length, light intensity, farm activity, presence of predators and fish size. Other less frequent environmental events such as storms and algal blooms can also have short term but very pronounced effects upon feed intake. Each species has a preferred feed pattern that varies according to size and season (Blyth *et al* 1997). It is therefore fundamentally important that these preferred periods of feed intake are determined and appropriate amounts of feed are delivered in a manner allowing satiation of all individuals. It has however proved difficult to monitor the feeding process when water conditions are turbid, as is common in tropical estuary areas typical of many existing farms in SE Asia.

Figure 1 shows the transition from wet feed to extruded pellets since 1968 in the Norwegian salmon industry. Feed conversion ration has made great improvements with each leap to better quality food. The use of trash fish, still a wide spread practice in SE Asia, can also cause major problems for the fish farming industry. A large proportion of this moist feed is lost as the feed items are unstable in water and break up upon entry to the water column. Hence many particles are easily lost to the surrounding environment, reducing feeding efficiency and increasing nutrient loadings beneath cages. In addition, trash fish as an unprocessed feed ingredient is a major potential vector for disease transmission. In Japan mortality was significantly reduced and growth enhanced by switching from trash fish to pelletized diets, due to a reduced feed wastage and subsequent improvements to fish health and survival. All major industrialized fish farming industries have moved from trash fish to pelletized diets with the exception of those relying on capture of wild fish juveniles for grow-out. Examples are South Australia tuna and Japanese yellow tail kingfish where moist pellets are preferred by fish unaccustomed to dry pellets. It is possible to wean wild stock given sufficient time, though this technique requires further research. However, in the long term, closing the production cycle through development of hatchery techniques for target species is considered essential in the process of moving from moist to dry feeds.

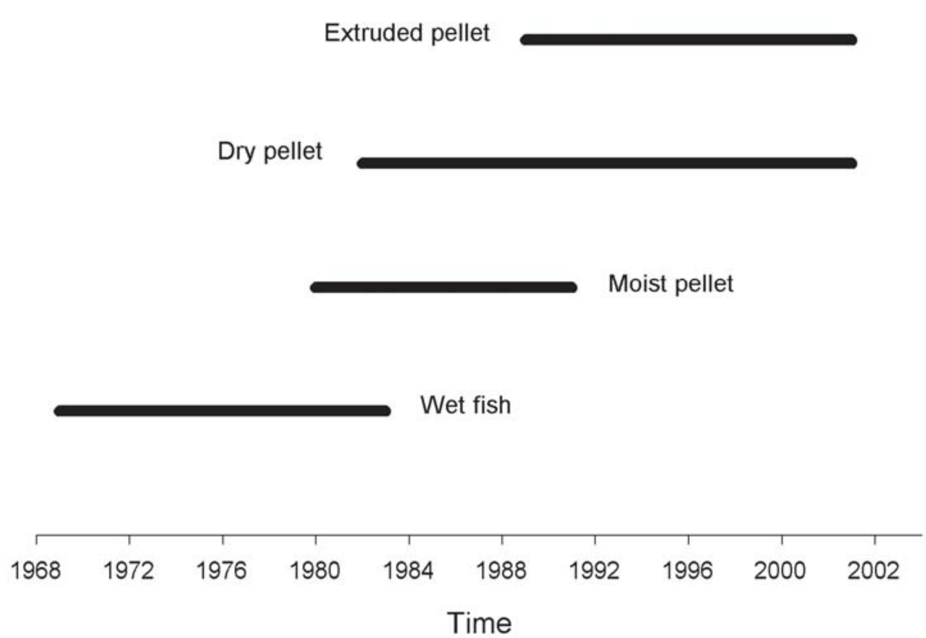

Figure 1: Showing transition of feed types (whole fish – moist pellet – dry pellet) in the Norwegian salmon industry since 1968.

Intensive salmon farming - using the latest pelletized diets along with modern feeding technology - has benefited from huge improvements in feed efficiency and increased ease of feed handling. Improvements due to the use of sensor-based feeding systems of 10-30% in growth (SGR) and 10-20% in feed conversion ratio (FCR) are possible as seen in the Norwegian salmon industry (*Salmo salar*), (Figure 2). This has been accompanied by a decrease in the cost of production (Figure 2, Vassdal 2001). Other factors have also contributed to this cost of reduction such as genetic improvement, lower disease and better husbandry practice.

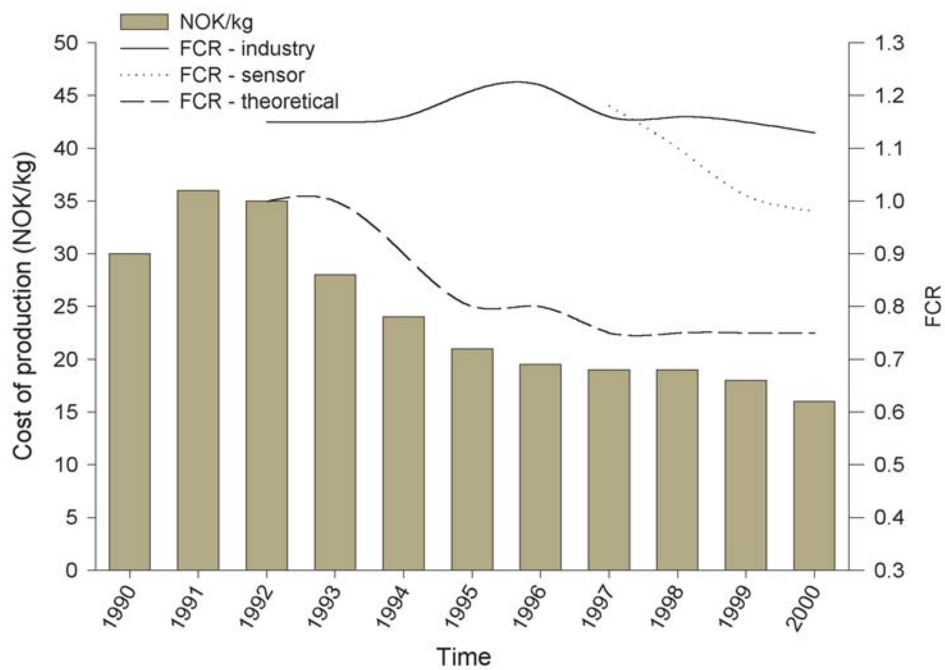

Figure 2: Graph showing Norwegian salmon cost of production, feed conversion ration (industry average, theoretical and farms using sensor based feed control) from 1990-2000.

Research and commercial results from the Japanese yellow tail kingfish, *Seriola quinqueradiata*, and the red sea bream *Pagrus major* have also demonstrated significant improvements with the introduction of such feed control technology (Nutreco unpub. data). Recent work on Atlantic salmon, European sea bass (*Dicentrarchus labrax*) and Gilthead sea bream (*Sparus aurata*) by Noble 2002 and Andrew *et al.* 2002 has indicated that modern feed control technologies can also provide a major benefit to fish health and welfare through reduced levels of competition during feeding bouts, leading to reduced aggression and stress, which can in turn promote a reduction in disease susceptibility. Swimming speeds associated with feeding bouts was also found to be less in fish that are fed completely to satiation using sensor based systems, indicating reduced energy expenditure per meal. Hence ensuring that fish are fed to satiation at each meal is critical to performance and well-being.

4. Environment

Environmental considerations such as solids and nutrient deposition beneath cages is also important. Control of total nitrogen and phosphorus input is also a key to healthy environs and fish. Good quality, highly digestible food and minimization of waste food is the key to managing these parameters. A 24% reduction in carbon deposition beneath cages was found in modeling work carried out by Telfer & Beveridge 2001 on sea bass cages in Spain when comparing modern sensor based feeding technology with conventional feeding methods. Minimum or zero waste feed should be the target of any aquaculture operation.

5. Current practices in Malaysia and Thailand

Several commercial farms were visited in Malaysia and Thailand, two using wooden cages (Penang, Krabi) and one using HDPE cages (Langkawi). Fisheries research facilities were also visited which consisted of wooden cage systems. (refer to Figures. 3-14 in Annex 1). The species farmed at these sites included Asian sea bass - *Lates calcarifer*, Mangrove jack – *Lutjanus argentimaculatus*, Red emporer – *Lutjanus sebae,* Tiger grouper – *Epinephelus fuscoguttatus,* Orange spotted grouper - *Epinephelus coioides,* Giant grouper – *Epinephelus lanceolatus,* White spotted snapper - *Lutjanus rivulatus,* Mouse grouper – *Cromileptes altivelis,* Cobia - *Rachycentron canadum.* Other species such as Coral trout – *Plectropomus leopardus* were being studied.

Culture areas ranged from full marine, estuary to brackish water lake impoundments. Wooden cages were locally made with small floating houses for living and operational activities or in the case of the sea bass lake culture, wooden poles rammed into the lake bed, with walk ways between the poles that supported the nets. Cage sizes were generally 2x2x2m deep for nursery and 4x4x3m deep for grow-out. They were clustered in groups of 100-300. This arrangement would lead to very poor water flow in the center of the system which would contribute to fish stress and disease. Nets were generally knotted polyethylene being quite abrasive to fish skin which would also contribute to disease.

Feed consisted almost entirely of trash fish except for one farmer that occasionally used pelletized diet when trash fish was unreliable due to supply and quality (NB. Trash fish use would be a major contributor to fish disease and pollution of the surrounding environment as seen from studies in Norway and Japan). Adult fish were generally fed twice a day per day, while juveniles were fed by hand multiple times per day or with net bags containing pellets left in the cage particularly for fry, or net trays with trash fish for fry. Feeding generally occurred for juveniles/fry x 3-4 per day at 07:00,12:00,17:00-18:00 (<50g). For adults of 100g+ x 2 meals per day was normal at 07:00 17:00-18:00. Fish were fed to satiation each meal with visual surface response as an indicator to cease. No daily feed records for individual cages were kept only monthly total farm input and output. Modern farming practice requires daily records of all farm inputs for production performance control and export trace ability regulations. Feed conversion ratio varied from 4-9:1 depending on quality of trash fish. Adoption of a pelletized diet would see a large reduction in FCR and improvement in growth and the environment. Growth Rates varied by species but in general the farmers would grow the fish up to 600g in 8 months. Maximum stocking densities achievable were 6kg/m^3. This is lower than the 20kg/m^3 currently occurring for *L. calcarifer* in modern cage technology in Australia. The wooden cage design, poor water flow, shallow depth, low BOD all contribute to poor stocking densities observed in these systems.

Many diseases occur in species farmed in the wooden structures (e.g. flukes, bacterial, viral). Some are transferred from hatchery with fingerlings or in the trash fish. The cycle is perpetuated by overlapping year classes (see Leong, 2001). Stock control needs to occur and specific pathogen free (SPF) broodstock need to be sought. Government regulation is important to control this part of the industry. Hygiene and the cessation of trash fish will improve conditions at the grow-out facility. Grow-out in better flushed environments with modern cages will minimize disease also.

6. Future strategies for improved production

Current farming practice in the areas visited were based on wooden cage structures designed for shallow water ways, low water current flows and to match the economic situation regarding lack of access to capital. Future industry expansion must be accompanied by a move into deeper well flushed environs which will necessitate different cage design/material and management systems similar to those used in the salmon sector and/or Japan. Larger cage systems also require more mechanization than the present systems e.g. net changing equipment, feed distribution and handling equipment, feed monitoring technology and larger offshore vessels adapted for limited processing as well as supporting the previous tasks.

The level of education on the farm must also increase to be able to operate these new systems. Institutions must take a more active role in training aquaculture technicians to extend improved practice and research results through the region.

Disease free stock is paramount, SPF stock must be an objective of any industrial growth. State of the art hatcheries, reliable supply of fingerlings is also a requirement for the success of this industry.

7. Economic Comparison of several farming techniques

Present production performance information and cage system configurations were surveyed, within the scope of this limited study. This data was then used in a model to analyze the economics of different farm styles. Currency calculations were made in Malaysian Ringgit, RM (Tables 1-3).

Three different farming techniques were modeled and then the financial return from each system per year and per crop was calculated based on an annual production of 14 tonnes. The three systems considered were, (1) wooden cage system & trash fish; (2) wooden cage, dry pelletized feed & feeding technology and (3) large steel cages, dry pelletized feed & feeding technology.

The number of cages required to grow 14.4 ton per annum from each system was determined and was greater for system (1) compared to (2) & (3). This reflected in the case of (2), improved survival, from the use of dry feeds and for (3) larger cages and improved survival from the use of dry feeds.

The Feed Conversion Ratio (FCR) was higher with trash fish at 7:1 compared to dry diets at 1.5:1 for both system (2) & (3). Although total feed cost was higher for pelletized diets (2,000 cf. RM 200 per ton) this wad far out weighed by better growth (+ 15%), survival (80% cf. 50%) and lower capital costs (Table 1).

The cost of capital infrastructure was higher for (3) which reflected the need for mechanical methods to service larger steel cages. After deduction from all expenses, system (3) showed a 52.6% improvement in net profit per annum compared to system (1) while system (2) showed a 16% improvement in net profit per annum over system (1).

Table 1: Shows the underlying assumptions in the model. Currency is Malaysian Ringgit (RM).

	System 1 **Trash fish** **Hand feeding** **Small wooden cages**	**System 2** **Dry Feed &** **Feeding technology** **Small wooden cages**	**System 3** **Dry Feed &** **Feeding technology** **Larger steel cages**
Cage Size	4x4x3	4x4x3	12x12x8
Fish Per Cage	500	500	30,000
No. of Cages	96	60	1
Cost of Fingerlings	2	2	2
Size of Fingerling (grams)	2	2	2
Harvest Size (grams)	600	600	600
Survival (%)	50%	80%	80%
Production Time (months)	8	7	7
Economic FCR	7.0	1.5	1.5
Feed Cost per tonne – (RM)	200	2,000	2,000
Farm Gate Revenue (kg)	30	30	30
Average Wage	3,000	3,000	30,000
No of Employees per Cage	0.10	0.10	0.50
Capital – Cages	3,000	3,000	70,000
Capital - Feeding System	0	6,000	25,000
Capital – Infrastructure per site	5,000	5,000	70,000
Depreciation Rate	25%	25%	25%
Other Expenses per cage	300	300	10,000
Production per Crop (t)	14.40	14.40	14.40

Please note that each farm has been structured to produce the same production volumes each crop (14.4 ton). Costs and performance data gathered on existing farming methods in SE Asia, Japan and Norway have been used in the model.

Table 2: Shows the profit and loss per crop and per annum in RM.

Profit and Loss Comparison	System 1 Trash fish & manual feeding wooden cages	System 2 Dry feed & feeding technology wooden cages	System 3 Dry feed & feeding technology steel cages
	RM	RM	RM
Revenue			
Fish sales	432,000	432,000	432,000
Expenses			
Fingerlings	96,000	60,000	60,000
Feed	20,160	43,200	43,200
Labour	28,800	18,000	15,000
Depreciation	48,833	79,479	24,063
Other Expenses	28,800	18,000	10,000
Total Expenses	222,593	218,679	152,263
Net Profit per Crop	**209,407**	**213,321**	**279,738**
Crops per Year	**1.50**	**1.71**	**1.71**
Net Profit per annum	**314,110**	**365,693**	**479,550**

Table 3: Shows the cost of production per kg in RM.

Profit per Kg	**System 1 RM/Kg**	**System 2 RM/Kg**	**System 3 RM/Kg**
Revenue per kg	30.00	30.00	30.00
Expenses			
Fingerlings	6.67	4.17	4.17
Feed	1.40	3.00	3.00
Labour	2.00	1.25	1.04
Depreciation	3.39	5.52	1.67
Other Expenses	2.00	1.25	0.69
Total Expenses	15.46	15.19	10.57
Net Profit	14.54	14.81	19.43

Please note that method 1 produces fewer crops per year.

8. Recommendations

1. Develop sea cage research facilities in conjunction with Fisheries Institutes and key private sector groups.
2. Encourage private sector to develop modern farming practice.
3. Introduce pelletized diets.
4. Upgrade existing cage technology (from wooden systems to plastic/ HDPE or steel) to allow expansion into better “flushed” environments which typically have higher wave action. Spread out the farm, existing cages systems are clustered allowing little flushing of the central cages. Low DO and exchange leads to disease conditions and higher mortalities.
5. Develop core farming competence - technical exchange programs for training staff in the detail of husbandry practice (feeding, disease management, net management, data control) and knowledge of the key indicators (SGR, FCR etc.).
6. Introduce feed management, data management systems and training programs
7. Develop husbandry practice to control disease.
8. Develop integrated hatchery – grow-out chain system eg. SALTAS model.
9. Develop disease screening for imported fry, broodstock.
10. Select SPF (Specific Pathogen Free broodstock).
11. Site selection, avoid grouping farms too close, disease transfer minimization.
12. Change to better net technology from knotted polyethylene nets which can contribute to skin abrasion. Use steel wire of nylon knotless.
13. Improve environment through adoption of sensor system technology.

The overriding economic consideration in this discussion is that the lack of capital may provide a major barrier to adopting advanced and sustainable sea cage systems and husbandry methods. Significant capital is required to build the farm and running costs are higher, particularly palletized feed costs. The temptation will always exist that a farmer with limited resources would switch back to cheap trash fish from dry diets, which is a problem seen in the Japanese yellowtail farming sector. However, the sector must adopt new practice if it is to survive and grow to meet the ever increasing food demand in the region.

9. Acknowledgements

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11. Annex 1 - Figures

Figure 3: Typical wooden 4x4x3m cages at Bukit Tambun, Penang

Figure 4: Cages at Bukit Tambun, Penang with living quarters

Figure 5: Sea bass, *L. calcarifer*, pole cages at Songkla, Thailand

Figure 6: Sea bass, *L. calcarifer* pole cages at Songkla, Thailand

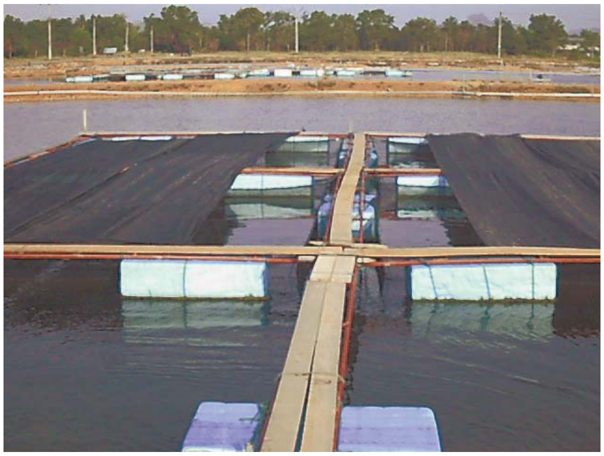

Figure 7: Research cages in ponds at Krabi Research Station, Thailand

Figure 8: Typical Thai sea cage farm at Phangnga.

Figure 9: Typical estuary sea cage farm in Thailand, Phangnga

Figure 10: Trash fish, typical feed used in Thai and Malaysian sea cage culture

Figure 11: Brood stock wooden sea cage holding facility, Phangnga Coastal Aquaculture Development Centre, Thailand

Figure 12: Extruded pelleted diet, Skretting Australia, used at Langkawi Seafarms, Malaysia

Figure 13: HDPE 5x5m nursery cages at Langkawi Seafarms, Malaysia

Figure 14: Grow-out cages at Langkawi Seafarms, Malaysia 50m circ. HDPE

Figure 15: Typical 12x12x10m red sea bream steel cage with AQ1 research feeding system in Japan

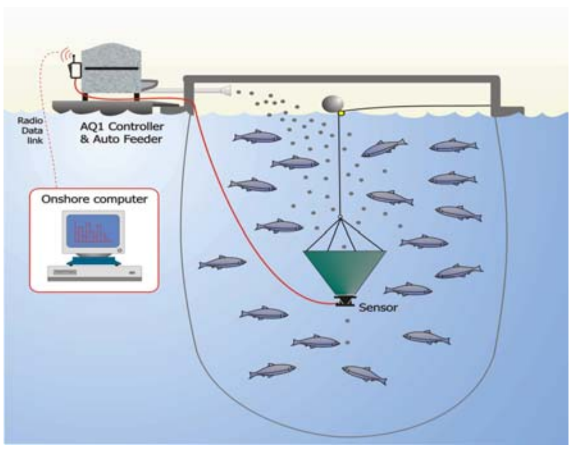

Figure 16: Schematic diagram showing AQ1 research feeding system

Figure 17: Red sea bream steel sea cage with FQ1 feeding system.

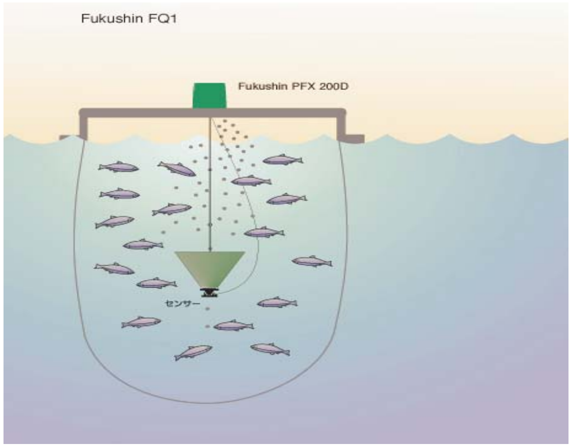

Figure 18: Schematic diagram showing FQ1 commercial feeding system

Figure 19: Typical bream farm in Spain using HDPE cage technology and AQ1 feeding system.

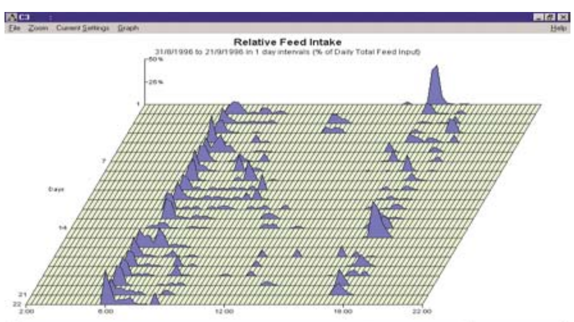

Figure 20: Example of feeding pattern data generated by AQ1 feeding system on Yellow tail kingfish; 2-3kg from Japan. (x axis = time of day; y axis = days; z axis = % of daily feed intake)

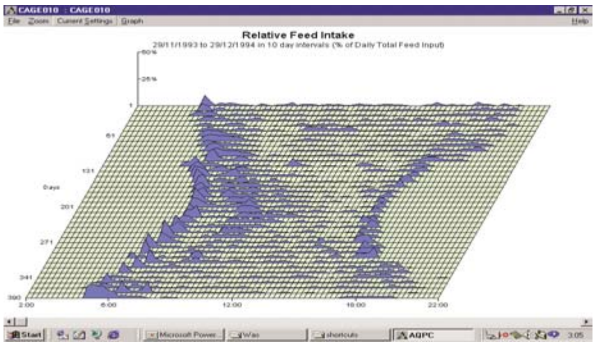

Figure 21: Example of feeding pattern data generated by AQ1 feeding system on Atlantic salmon in Tasmania; 0.4-6kg. (x axis = time of day; y axis = days; z axis = % of daily feed intake)