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Aquafeeds and the environment: policy implications

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Abstract

Aquaculture feeds and feeding regimes can play a major role in determining the quality and potential environmental impact or not of finfish and crustacean farm effluents. This is particularly true for those intensive farming operations employing open aquaculture production systems, the latter including net cages/pen enclosures placed in rivers, estuaries or open-water bodies, and land-based through-flow tank, raceway or pond production systems. This is perhaps not surprising since the bulk of the dissolved and/or suspended inorganic and/or organic matter contained within the effluents of intensively managed open aquaculture production systems are derived from feed inputs, either directly in the form of the end-products of feed digestion and metabolism or from uneaten/wasted feed, or indirectly through eutrophication and increased natural productivity.

So, as to limit the potential negative environmental impacts of feeds on aquaculture effluents, the major approaches taken by government authorities within major aquaculture-producing countries have included (1) requiring the treatment of farm effluents prior to discharge, through the use of settlement basins, specific filtration devices, waste water treatment systems, etc., (2) limiting the concentration of specific dissolved/suspended inorganic/organic materials and/or nutrients contained within the effluent discharged from the farm, (3) establishing maximum permissible amounts of specific nutrients (such as total nitrogen or phosphorus) that the farm is able to discharge over a fixed time period, (4) limiting the total number of licenses that can be issued and/or size of farm, depending upon the vicinity of other farming operations and the assimilative environmental carrying capacity of the receiving aquatic ecosystem, (5) limiting or fixing the total quantity of feed the farm is able to use over a fixed time period, (6) fixing maximum permissible specific nutrient levels within the compound feeds to be used to rear the species in question, (7) banning the use of specific potentially high-risk feed items such as fresh/trash fish and invertebrates, (8) banning the use of certain chemicals on-farm, including specific chemical therapeutants/drugs and chemicals (i.e., potentially toxic herbicides and pesticides, etc., (9) prescribing minimum feed performance criteria, such as specific levels of allowable dust/fines, feed efficiency or nutrient digestibility, (10) requiring the use of specific Codes of Conduct, including appropriate Best/Good Management Practices for farm operations, including feed manufacture and use, and environmental management, (11) requiring

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the development of suitable farm/pond sediment management strategies for the storage and disposal of sediments, or (12) requiring the implementation of an environmental monitoring program.

The paper describes the merits and demerits of each of the above initiatives, with specific country examples, and attempts to offer guidance for the development of government policies aimed at regulating off-farm effluents and outputs rather than regulating on-farm feed inputs and feeding practices.

Keywords: Aquafeeds; Nutrients; Eutrophication; Culture systems; Environment; Policy

1. Introduction

The production of farmed aquatic animals is dependent upon the provision and supply of nutrient inputs, either directly in the form of food organisms and/or compound aquafeeds, or indirectly in the form of fertilizers. It follows that the rate of supply and assimilation of these nutrient inputs on-farm will play a major role in dictating the nutrient and/or waste outputs from the production facility (Lopez Alvarado, 1997; McGoogan and Gatlin, 2000; Sugiura and Hardy, 2000; Cho and Bureau, 2001). Moreover, these outputs and their environmental impacts (or not) will, in turn, vary depending upon the farming system employed (open or closed farming systems), on-farm feed/nutrient and water management, and the assimilative capacity of the surrounding aquatic and terrestrial environment (European Commission, 1995; Tacon et al., 1995; Phillips, 1997; Asian Development Bank and Network of Aquaculture Centres in Asia-Pacific, ADB/NACA, 1998; Beveridge et al., 1998; Black, 2001; Lawrence et al., 2001; Moss et al., 2001; Wu, 2001; Tacon, 2001).

2. Aquaculture waste outputs

Aquaculture wastewater outputs and loads vary widely, depending upon the species cultured and farming system and aquatic environment employed (National Aquaculture Association, NAA, 1998; Boyd and Queiroz, 2001). Wastewater outputs usually consist of dilute farm effluents (i.e., untreated or treated rearing water) and, in the case of land-based farming operations, may also include concentrated farm sediments. Sediments are also contributed to the environment from marine net pens.

Effluents are generally discharged on a continuous basis over the production cycle (although not always) and usually contain both dissolved and suspended inorganic and organic material. On the other hand, sediments from land-based systems are generally collected intermittently or at the end of the production cycle and consist of a mixture of inorganic and organic particulate material.

Wastewater outputs are usually mainly derived from on-farm feed/nutrient inputs, either directly in the form of uneaten/leached feeds, animal digesta and excretory products, and/or indirectly through water eutrophication and consequent increased natural productivity.

Apart from feed nutrients/metabolities and planktonic biota, depending upon the farming system and husbandry practices employed, aquaculture wastewaters may also contain

- residues of specific chemicals used within aquafeeds as medicants or feed additives, and/or during normal farm husbandry operations, including fertilizers (Table 1),
- particulate/nonparticulate matter derived from pond soil erosion and/or from agricultural/industrial run-off/leaching (including possible aerial contaminants through precipitation), and
- viable aquatic pathogens, dead or diseased animals, including live animal escapees (Gill, 2000; Goldburg et al., 2001; Subasinghe et al., 2001).

Table 1
Major category of chemicals used in aquaculture[a]

Chemicals and their application
Chemicals associated with structural materials: plastic additives—stabilizers, pigments, antioxidants, UV absorbers, flame retardants, fungicides, and disinfectants; antifoulants—tributyltin
Soil and water treatments: flocculants—alum, EDTA, gypsum (calcium sulphate), ferric chloride; alkalinity control—lime/limestone; water conditioners/ammonia control—zeolite, *Yucca* extracts, grapefruit seed extract (KILOL); osmoregulators—sodium chloride, gypsum; hydrogen sulphide precipitator—iron oxide
Fertilizers: inorganic salts—limestone, marl, nitrates, phosphates, silicates, ammonium compounds, potassium and magnesium salts, trace element mixes; organic fertilizers—urea, animal and plant manures
Disinfectants: general—formalin, hyprochlorite, iodophores—PVPI, sulphonamides, ozonation; topical—quaternary ammonium compounds, benzalkonium chloride
Antibacterial agents: β-lactams—amoxycillin; nitrofurans—furazolidone, nifurpirinol; macrolides—erythromycin, phenicols—chloramphenicol, thiamphenicol, florphenicol; quinolones—nalidixic acid, oxolinic acid, flumequine; rifampicin, sulphonomides, tetracyclines—oxytetracycline, chlortetracycline, doxycycline
Therapeutants and other antibacterials: acriflavine, copper compounds, dimetridazole, formalin, glutaraldehyde, hydrogen peroxide, levamisole, malachite green, methylene blue, niclosamide, potassium permanganate, trifluralin
Pesticides: ammonia, azinphos ethyl, carbaryl, dichlorvos, ivermectin, nicotine, organophosphates, organotin compounds, rotenone, saponin, trichlorofon, teased cake, mahua oil cake, derris root powder, lime, potassium permanganate, urea, triphenyltin, copper sulphate
Herbicides/algicides: 2,4-D, Dalapon, Paraquat, Diuron, ammonia, copper sulphate, simazine, potassium ricinoleate, chelated copper compounds, food colouring compounds
Feed additives: acidifiers—citrates; antioxidants—butylated hydoxyanisole, butylated hydroxytoluene, ethoxyquin, propyl gallate; binders—animal protein, mineral (bentonite, magnesite), plant, seaweed, synthetic (urea formaldehyde, polyvinyl-pyrrolidone); feed enzymes; emulsifiers/surfactants—natural, synthetic; growth promoters—natural, synthetic; minerals—major and trace; pigments—food dyes, carotenoids (natural, synthetic); synthetic vitamins, amino acids and feeding attractants; immunostimulants, probiotics, mould inhibitors—natural, synthetic)
Anaesthetics: benzocaine, carbon dioxide, metomidate, quinaldine, phenoxyethanol, tricaine methanesulphonate
Hormones: growth hormone, methyl-testosterone, oestradiol, ovulation-inducing drugs, serotonin
Fuels and lubricants: petroleum products—kerosene, petrol, diesel, oil
Environmental contaminants/pollutants—heavy metals/other metals—mercury, lead, mercury, arsenic, cadmium, chromium, copper, iron, manganese, nickel, selenium, silver, zinc; Chlorinated insecticides—DDT, dieldrin, lindane and their degradation products; PCBs and Dioxins

[a] Compiled from GESAMP, 1997; Boyd and Massaut, 1999; FAO/Network of Aquaculture Centres in Asia-Pacific (NACA)/World Health Organization (WHO), 1999; Arthur et al., 2000; Barrows, 2000.

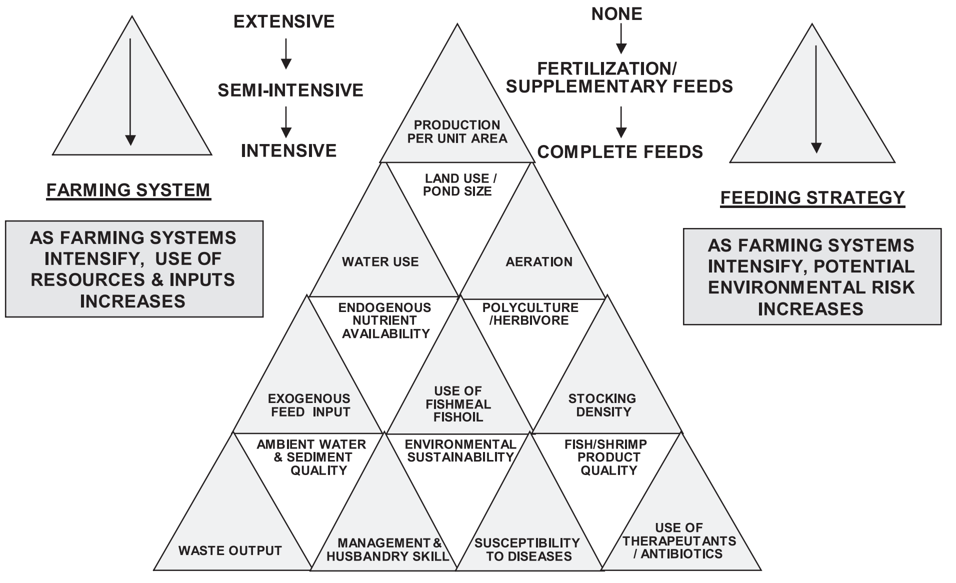

Fig. 1. Main differences between conventional extensive, semi-intensive, and intensive farming systems in terms of resource use and potential environmental risk.

In general, the higher the intensity and scale of production, the greater the nutrient inputs required and consequent risk of potential negative environmental impacts emerging from the aquaculture facility through water use and effluent discharge (Fig. 1). In the above respects, aquatic food production systems are no different from livestock farming (Coucil for Agricultural Science and Technology, CAST, 1999; Barrett, 2001; Delgado et al., unpublished).

Whereas in terrestrial animal farming, production is restricted to a handful of warm-blooded livestock species under relatively uniform rearing conditions, aquatic animal farming systems are currently based on the culture of a multitude of cold-blooded species (in 2000, these included 131 finfish species, 42 mollusk species, and 27 crustacean species; FAO, 2002) within an equally wide range of production units, farming systems, and environments.

3. Policies aimed at reducing environment impacts

To date, the major approaches taken by government authorities within the major aquaculture-producing countries for minimizing or reducing the potential negative feed-related environmental impacts of farm effluents have included

- requiring the treatment of farm effluents prior to discharge, through the use of settlement basins, specific filtration devices, wastewater treatment systems, etc.

Examples: Australia (shrimp farmers; Donovan, 1997), Denmark (European Commission, EC, 1995);

- limiting the concentration of specific dissolved/suspended inorganic/organic materials and/or nutrients contained within the effluent discharged from the farm. Examples: Canada (British Columbia: Anon., 2001a), selected states in the USA (Hardy, 2000; Goldburg et al., 2001), most European countries (European Commission, EC, 1995);
- establishing maximum permissible amounts of specific nutrients (such as total nitrogen or phosphorus) that the farm is able to discharge over a fixed time period. Examples: Australia (shrimp farmers; Donovan, 1997), Denmark (European Commission, EC, 1995);
- limiting the total number of licenses that can be issued and/or size of farm (and hence production), depending upon the vicinity of other farming operations and the assimilative environmental carrying capacity of the receiving aquatic ecosystem. Examples: Australia (shrimp farmers; Donovan, 1997), Denmark (European Commission, EC, 1995), Norway (Anon., 2001b);
- limiting or fixing the total quantity of feed the farm is able to use over a fixed time period. Examples: Denmark (European Commission, EC, 1995), Norway (Anon., 2001b);
- fixing maximum permissible specific nutrient levels within the compound feeds to be used to rear the species in question. Examples: Denmark (European Commission, EC, 1995), Thailand (Boonyaratpalin and Chittiwan, 1999; Corpron and Boonyaratpalin, 1999);
- banning the use of specific potentially high-risk feed items such as fresh/trash fish and invertebrates, and/or only permitting the use of artificial feed. Examples: Australia (shrimp farmers; Donovan, 1997);
- banning the use of certain chemicals on-farm, including specific chemical therapeutic agents/drugs and chemicals (i.e., potentially toxic herbicides and pesticides). Examples: Australia (shrimp farmers; Donovan, 1997), USA (Boyd and Massaut, 1999; Goldburg et al., 2001), Asia/general (GESAMP, IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environment Protection, 1997; Arthur et al., 2000);
- prescribing minimum feed performance criteria, such as specific levels of allowable dust/fines, feed packing material, feed efficiency or nutrient digestibility. Examples: Australia (shrimp farmers; Donovan, 1997), Denmark (European Commission, EC, 1995);
- requiring the use of specific Codes of Conduct, including appropriate Best/Good Management Practices for farm operations, including feed manufacture and use, and environmental management. Examples: Australia (Environmental Code of Practice for Australian Prawn Farmers: Donovan, 1997), Belize (shrimp farming; Dixon, 1997), Canada (British Columbia: Anon., 2001a), EU (Irish Salmon Growers Association, 1991; British Trout Association, 1995), Thailand (Tookwinas et al., 2000), shrimp farming (Boyd, 1999; Boyd et al., 2001), feed management (Davis, 2001), feed manufacture (FAO, 2001), general (Food and Agriculture Organization of the United Nations, FAO, 1997; Boyd et al., 2001; Tacon and Barg, 2001);

- requiring the development of suitable farm/pond sediment management strategies for the storage and disposal of sediments. Example: Australia (shrimp farmers; Donovan, 1997);
- requiring the implementation of an environmental monitoring program. Examples: Australia (shrimp farmers; Donovan, 1997), Canada (British Columbia: Anon., 2001a), Norway (Anon., 2001b; Ervik et al. 1997), USA (selected states: Goldburg et al., 2001), EU (European Commission, EC, 1995; Black, 2001;), General (Barg, 1992; Wu, 2001).

4. No single solution

The above diversity of policy options reflects the wide variety of farming systems and species cultivated around the world and the different approaches used by government authorities and/or farming associations to deal with the discharge of effluents and waste waters from their aquaculture operations.

Of the different countries where regulations exist, Denmark stands out as having one of the most comprehensive and stringent environmental aquaculture regulations (Table 2). It is perhaps interesting to note that aquaculture production within the country has remained relatively static since the introduction of the Danish aquaculture law in 1989. Total aquaculture has remained constant at around 40,000 mt since 1990, and Denmark is ranked 35th in the world in terms of total aquaculture production by weight (43,609 mt in

Table 2
Environmental legislation in the European Union with regard to aquaculture development and the environmental control measures of existing aquaculture operations[a]

Country	EIA[b] need	Limit on production	Limit on N and P load	Diet contents	Maximum FCR[c]	Water treatment
Belgium	N	N	N	N	N	N
Denmark[d]	N	Y	Y	Y	Y	Y
Germany	N	N	Y	N	N	N
Greece	Y	N	N	N	N	N
Spain	N	N	N	N	N	N
France	Y	Y	N	N	N	N
Ireland	Y	Y	Y	N	N	Y/N
Italy	Y/N	N	Y	N	N	N
Netherlands	N	N	Y	N	N	Y/N
Portugal	N	N	N	N	N	N
UK—England and Wales	N	N	Y	N	N	Y/N
UK—Scotland	N	Y	Y	N	N	Y/N

N = no; Y = yes.

[a] European Commission (1995).

[b] EIA = environmental impact assessment.

[c] FCR = food conversion ratio.

[d] Danish regulations include restrictions on feed use, minimum gross energy levels of 6.0 Mcal/kg, maximum nitrogen and phosphorus levels of 8% and 1%, dust content not to exceed 1%, maximum FCR of 1:1 (I:1.2 in seawater, increase between influent and effluent concentrations (freshwater fish farms) must not exceed biological oxygen demand (BOD) of 1 mg/l, suspended solids (SS) 3 mg/l, total phosphorus 0.05 mg/l, total ammonia 0.4 mg/l, and total nitrogen 0.6 mg/l.

2000; FAO, 2002). The main reason for these strict environmental regulations is due to the importance given toward recreational fisheries in Denmark and the consequent need to maintain a pristine aquatic environment (EC, 1995).

Clearly, within those countries where aquaculture is viewed as an important provider of food and/or source of income or employment, it is important that government policies be flexible (so as to address the diversity of species, farming systems, and possible rearing environments within the country in question), practical and enabling (so that they facilitate the continued growth of the sector), and protective of the environment (in that they both preserve the aquatic environment for all other users, while protecting the aquaculture sector from other water users and potential environmental polluters). In this respect, we feel that, as with terrestrial agricultural food production systems, policies aimed at regulating off-farm effluents and outputs would be more beneficial for the continued diversity and health of the sector rather than regulating on-farm feed inputs and feeding practices.

These latter policies should be used with reluctance in conditions where measuring effluents is exceptionally difficult, as for instance, in the case of open-ocean aquaculture. The main rationale behind this preference for targeting regulations aimed at effluent control is that there are many suitable ways of supplying nutrients to the target species and of managing nutrients and water on-farm, and that the net effect of appropriate farming activity is not detrimental to the aquatic environment and to other potential and future users.

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