Strategic framework for seafood waste management

July 2005

Technology & Training

SR574

ISBN – 0903941 18 x

Working with the seafood industry to satisfy consumers, raise standards, improve efficiency and secure a sustainable future.

The Sea Fish Industry Authority (Seafish) was established by the Government in 1981 and is a Non Departmental Public Body (NDPB).

Seafish activities are directed at the entire UK seafood industry including the catching, processing, retailing and catering sectors.

Seafish Technology and Training: We promote the sustainable use of fish resources, quality, the reduction of waste and the improvement of safety through practical applied research.

We also develop standards, training programmes and learning support materials. We also promote training opportunities for all sectors of the sea fish industry through a national network of Group Training Associations. Quality award schemes are available for processors and friers.

ISBN – 0903941 18 x

Seafish Technology & Training Division

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Date: June 2005

Strategic Framework for Seafood Waste Management

Summary:
In recent years, waste policy and legislation has focussed on the protection of resources, promoting sustainable utilisation and reducing emissions to the environment. Recently, concerns about farm animal diseases, particularly those transmissible to man, have introduced additional controls which have resulted in the closure of some of the existing routes for utilising waste and added further restriction and costs to waste disposal. This has affected the seafood industry as the controls apply to seafood waste.

The seafood processing industry generates a significant amount of waste. It is estimated that approximately 312,875 tonnes of seafood processing waste is produced each year in the UK. Approximately 80% (249,950 tonnes) of this is finfish waste whereas 20% (62,925 tonnes) is shellfish. It has not been possible to estimate the quantities of waste produced by other sectors of the industry.

During processing, much is done to maximise the yield of direct edible products but the production of waste or by-products is inevitable. Much of this is generally discarded as waste or as a low value by-product.

The majority of finfish processors have access to fishmeal and other income generating routes, which currently generate approximately £5.5 million each year. However in regions including Central Scotland, Northern Ireland, East and South-West England, finfish processors largely pay to dispose of waste. Current disposal costs are approximately £1.85 million each year. In these regions, they are concerned that the situation will get worse and costs will rise significantly in future.

The shellfish industry largely pays to dispose of its waste through a number of routes, although landfill is still the major route for shellfish waste disposal across all the UK. Current disposal costs are approximately £2.7 million each year. Over 80% of shellfish processors expect the situation to get worse when landfill is no longer available, as there is limited availability of alternative waste management facilities at the moment. Costs are expected to rise significantly as processors may have to transport waste further to suitable outlets.

There are many options for seafood waste management that could help to resolve these problems. These have been assessed according to the principle of Best Practicable Environmental Option (BPEO) which includes the waste hierarchy. This is a standardised process for assessing waste management options to develop preferred options. It is a long and detailed process requiring evaluation of the process, level of technology required, complexity, legality, scale, costs, whether marketable products are produced, environmental impacts etc. This principle was applied to the range of options for seafood waste management, to provide a ranked list of options which could be available in the short, medium and long term.

Short term options include contracting existing solution providers and the commercial waste management industry, developing edible products such as mince and heads, direct animal feeding (bait), tying in with the established fishmeal infrastructure, landspreading, shell based products, cultch and disposal at sea. These should be looked at on a co-operative, regional approach to make them more cost-effective.

Longer-term options include crustacea based derivatives, fish protein hydrolysate, fish protein concentrate, enzymes, leather, fertilisers, collagen, gelatine, biofuels and pharmaceuticals which are all highly specialised with potential for producing valuable products. However there are many more uncertainties about these options and they would only be successful on a regional co-operative basis. Detailed feasibility studies are required before actual decisions about their feasibility and how they tie in with the BPEO framework can be made.

It is apparent that all the options require some further development before they would be available to industry. For the finfish sector this could largely involve developing regional collection schemes in areas where they pay for disposal, to enable them to tie in with the income generating fishmeal route. The shellfish sector will also benefit from a collective approach but may be limited to sending waste for disposal via an existing waste management route or, given the shortage of companies that treat shellfish waste, via other short-term options such as disposal at sea or land application. Different options will be more suitable for some regions and businesses than others, which makes it impossible to establish a definitive list of seafood waste management options. Therefore the seafood industry will need considerable help to resolve these problems.

On the basis of all the information collected, a strategic framework has been developed, setting out the ten year vision for seafood waste management. This is separated into three distinct aims and stages; all companies to achieve legal compliance as an immediate priority within two years; companies to generate economic return from waste by 2010 and; companies to ultimately aim to generate significant and profitable returns from waste by 2015.

Three overall action plans, based on these strategic aims, have been developed to help industry work towards more sustainable seafood waste management. These include detailed actions where they can be identified. Detailed actions for other stakeholders have not been identified at this stage, given the number of current uncertainties. Instead, action points with target dates milestones have been set out in a generic action planning ‘toolbox’ which contains a structured process to help stakeholders compile and implement specific regional plans.

In the short-term (2005-2007), the immediate priority is to raise awareness throughout industry and provide information to help companies achieve compliance as soon as possible. The initial emphasis for addressing the problems is to establish collaborative groups in key target regions who will evaluate and deliver solutions appropriate to that region.

In the medium-term (2005-2010), it is desirable to promote awareness of routes that can generate economic return and develop targeted, collaborative groups to develop these further. There are many more uncertainties within this process, with no guarantees of success. However an outline action plan providing the framework on which collaborative groups can evaluate the different options and assess their relative feasibility for their particular situations is included.

Generating significant and profitable return from waste is a much longer-term aim (2007-2015). For these options, a considerable amount of further assessment is required before decisions on their feasibility can be made. This necessitates further research, evaluation of markets and cost-benefits, handling, storage, infrastructure and logistics etc which may or may not lead to the establishment of a profit generating facility. Developing infrastructure to generate profits is a more prolonged process with no guarantees of success. It will require a significant level of collaboration between relevant organisations and specialists, requiring a much higher level of effort and resources. A generic action plan has been produced, giving an overall approach that can be adopted.

The development and delivery of the way forward requires commitment from Seafish, industry, devolved regional governments, environmental agencies, local authorities, funding agencies etc to help resolve current problems. This report provides the framework of how this can be achieved and details the stages that were necessary to produce this framework. It provides a brief overview of background policy and legislation, gives an estimation of the types, quantities and regional locations of seafood waste production, gives an overview of waste utilisation and disposal routes currently used by industry and identifies those regions with seafood waste disposal problems. It includes an assessment of different seafood waste management options in terms of their practicality to industry and perceived environmental impacts, which provides a list of preferred options for managing seafood waste in future.

Although the report is largely aimed at the processing sector, other parts of industry including port markets, fishmongers, wholesale markets etc should be included within any future developments as these sectors are also experiencing difficulties with seafood waste disposal.

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1. Introduction, purpose and scope

In recent years, waste policy and legislation has focussed on the protection of resources, promoting sustainable utilisation and reducing emissions to the environment. Recently, concerns about farm animal diseases, particularly those transmissible to man, have introduced additional controls which have resulted in the closure of some of the existing routes for utilising waste and added further restriction and costs to waste disposal.

This has affected the seafood industry as the controls include both finfish and shellfish waste. The industry faces major problems due to the current lack of infrastructure to treat different types of seafood waste, particularly shell, which is causing problems to companies in the processing, retailing and catering sectors throughout the UK.

In late 2004, Defra tasked Seafish with carrying out a review of the options available for managing seafood waste within the context of Governmental waste policy. This included the following objectives;

- Evaluating the current situation regarding seafood waste in the UK.
- Consideration of how long it would take industry to move towards full compliance with legislation and waste reduction initiatives.
- An assessment of the measures that would be required in the interim.

This report details the resulting strategic way forward. The scope of the work includes seafood processing waste or by-products, which are classed as parts of wild caught fish or shellfish that are discarded after the edible portions have been removed. Although it is largely targeted at the processing sector, other parts of industry including retail, catering, port auctions and the catching sector should also be considered within its overall context. Other sources of waste from industry and the finfish aquaculture (salmon and trout) sectors are not included.

The development of this review required consideration of Government waste strategy, including the waste hierarchy, and recommended methods for establishing preferred waste management options, which is based on the concept of best practicable environmental option (BPEO). The review was carried out by a small, multi-disciplinary team of Seafish employees. Direct surveys of industry were carried out to assess the current situation whereas extensive use of publications, existing knowledge and industry contacts were used for other areas.

This report produces a strategic framework for the seafood industry to move from the current difficulties towards the overall strategic aims of reducing waste, minimising costs and maximising revenue. This is set within a ten-year timescale with prioritised short, medium and long term objectives.

The report sets out the stages that were necessary to produce the strategic framework.

- A review of background policy and legislation, which was necessary to establish the baseline on which the strategic framework is based. (Section 2)
- A survey of the UK processing industry, which was undertaken to provide an overview of the current situation in industry. This includes an estimation of the different types, quantities and regional locations of seafood waste production. It also provides an overview of the waste utilisation and disposal routes currently available to industry and the sectors and regions currently experiencing or expecting difficulties. (Section 3)
- An assessment of different seafood waste management options in terms of their practicality to industry and perceived environmental impact. This provides a list of preferred options for managing seafood waste. (Section 4)

The strategic framework is outlined in Section 5.

2. Background policy and legislation overview

EU policies and directives, enacted through devolved UK legislation, are steering environmental practices across industry. Their overall aims are to reduce environmental impacts and work towards greater sustainability.

The production, utilisation, handling, transport and disposal of waste, particularly food and animal waste, is strictly regulated which impacts on waste management infrastructure. Anybody wishing to engage in waste related activities must be aware of all relevant policies and legislation before going down this route. This requires engaging with relevant authorities and regulators from the outset.

This chapter summarises the main policies on waste (Section 2.1) and gives an overview of relevant legislation (Section 2.2). These are not exhaustive but are necessary to provide the background on which the strategic framework was based.

For the purposes of this report the basic definition of waste is "any substance or object which the holder discards or is required to discard" and is taken from the EC directive 75/442/EEC on waste. In the context of seafood waste, this is defined as any part of the fish or shellfish which the processor discards after removal of the edible portion.

2.1 Waste Policy

2.1.1 EU waste policy

The Council Directive on waste (75/442/EEC) constitutes the legal framework for Community policy on waste management to limit its production. It was amended by the Waste Framework Directive 91/156/EEC in order to incorporate the guidelines set out in the Community Strategy for Waste Management in 1989. The main provisions of Directive 75/442/EEC as amended are;

- Definition of waste.
- Hierarchy of waste management principles (prevention, recovery, disposal).
- Proximity principle and self-sufficiency applying to waste for final disposal and the establishment of an integrated network of disposal installations.
- Obligates Member States to establish waste management plans.
- Permits for establishments and undertakings carrying out disposal and recovery operations.
- Polluter pays principle.
- Reporting requirements.

2.1.2 UK waste policy

Devolved regions in the UK have developed their own overall generic waste strategies (Refs 1, 2, 3), which spell out future policies on waste management. In general the strategies were developed to enable waste management to move from reliance on disposal through to obtaining value from waste (such as by composting or anaerobic digestion) and preventing or reducing waste in the first instance. They provide the basis on which waste is to be managed sustainably in future in the UK. This is a long-term vision, requiring Governments and Local Authorities to invest heavily in alternative, sustainable waste management facilities.

The Waste Strategy 2000 for England & Wales (Ref 1) outlines that for waste to be managed sustainably, decision makers need a framework on which to move in that direction. Waste management is a complex mix of solutions, requiring consideration of a number of factors. The process that is used for considering the relative merits of waste management options is the Best Practicable Environmental Option (BPEO) for the waste. BPEO is defined as:-

> 'the outcome of a systematic and consultative decision making procedure which emphasises the protection and conservation of the environment across land, air and water.

The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefits or the least damage to the environment as a whole, at acceptable cost, in the long term as well as in the short term'.

It is not a straightforward process as BPEO varies from product to product, from area to area and from time to time. In determining the BPEO, there are 3 main considerations;

- The waste hierarchy which is a conceptual tool used to rank waste management options. The waste hierarchy is comprised of Reduce, Reuse, Recover/Recycle, Energy Recovery and Disposal. The priority is to reduce waste wherever possible and then review all the options in the waste hierarchy to identify practicable solutions for different parts of the waste stream. The least favoured solutions are in the disposal category. It is likely that a range of different options will be developed, crossing all levels of the waste hierarchy.
- The proximity principle requires waste to be utilised or disposed of as close to the place of production as possible. This helps to reduce the environmental impact of transporting waste to other regions for treatment.
- 'Self sufficiency' requires waste to be treated in the UK, rather than exported to other countries.

Within these are many factors to consider including social, economic, environmental, land use and resource use impacts. Undertaking BPEO effectively is a very detailed process which can take a significant amount of time (Ref 4). The principle of BPEO has been used as a basis to establish this strategic framework for seafood waste management.

2.2 Waste Legislation

The main requirements of relevant legislation are summarised in this section but it is not an exhaustive list. As the legal situation is constantly evolving, it is advisable to seek further guidance from the relevant authorities on the latest developments. Further information on waste legislation is available in a Seafish paper (Ref 5).

The recovery or disposal of waste is subject to the Waste Framework Directive. Article 4 of the Directive requires member states to take the necessary measures to ensure that waste is recovered or disposed of without endangering human health and without using processes or methods which could harm the environment. The Directive also requires that the recovery and disposal of waste are subject to the need for permits. In the UK, the system of permitting is met through the waste management licensing system under part II of the Environmental Protection Act 1990 and the Pollution Prevention and Control regime (under the Pollution Prevention and Control Regulations 2000).

Exemptions from the need for a permit do exist within the Waste Framework Directive and UK domestic legislation, however, these are subject to the objectives of Article 4 and general rules concerning the activities, types and quantities of waste. For example, in the UK, exemptions from waste management licensing are provided in the Waste Management Licensing Regulations 1994 (as amended). However exempt activities must be registered with the competent authority.

2.2.1 Processors' Waste Disposal Facilities

The Food Hygiene (Fishery Products & Live Shellfish)(Hygiene) Regulations 1998 sets out the conditions under which fish and shellfish products must be produced in order to be placed on the market. This includes requirements for hygienic waste handling and disposal. Offal/viscera should be kept separate from products intended for human consumption. Onshore processing facilities must regularly remove waste from the processing area, either by continuous means or by holding the material in leak-proof, covered containers which should be removed when full. Containers for holding waste material must be watertight and corrosion resistant and should be designed to facilitate cleaning and disinfection. If waste material is to be stored overnight, it should be housed in a dedicated waste holding area.

2.2.2 Food & Feed Safety

The Animal By-products Regulation 1774/2002 (ABPR) specifies that any animal by-product (animal carcass, parts of animal carcasses or products of animal origin) not intended for human consumption must be disposed of through appropriate channels.

In descending order of risk, it defines three categories of by-product with specific storage, handling and disposal requirements (Table 1).

Table 1 Categories of Animal By-product materials and permitted treatments

Category	Type of raw material included	Storage and disposal requirements
1	• All body parts affected by TSE, pet/zoo/circus animals, experimental animals • Wild animals suspected of being infected with disease communicable to humans or animals, • Animals containing residues of environmental contaminants • Animal material collected when treating waste water from Category 1 processing plants and • Mixtures of Category 1 material with either Categories 2 or 3 materials or both	• Incineration • Processing in an approved Category • 1 processing plants (rendering) • Rendering followed by incineration • Rendering followed by landfill
2	• Mortalities • Animal by-products containing digestive tract or manure components • Animal material collected from treating waste water from slaughter houses or Category 2 processing plants • Products containing residues of veterinary drugs and contaminants listed in Group B(1) and (2) of Annex I to Directive 96/23/EC • Non-Category 1 by-products from non-member States. • Animals or parts of animals that have been slaughtered for human consumption, inc those killed to eradicate an epizootic disease • Mixtures of Category 2 material with Category 3 material	• Incineration • Processing in an approved Category 2 processing plants (rendering) • Rendering followed by incineration in approved plants • Rendering followed by landfill in approved plants • Certain marked material may be (i) used as an organic fertiliser, (ii) transformed in a biogas plant or (iii) buried in approved landfill sites • For material of fish origin, may be ensiled or composted (subject to approval).
3	• Parts of slaughtered animals for human consumption • Fish or other sea animals (exc. sea mammals) caught in the open sea for the purpose of reduction to fish meal • Fresh fish by-products from plants manufacturing fish products for human consumption.	• Incineration • Processing in an approved Category 3 processing plants • Rendering followed by incineration in approved plants • Rendering followed by landfill • Transformed into technical products at approved plants • Used as a raw material in pet foods & animal feeds • Transformed in a biogas or composting plant • For material of fish origin, ensiled or composted • Where authorised, used as a feed for zoo, circus, fur animal, hounds, maggot / worm (as bait)

Waste from seafood processors is typically Category 3, with the exception of shellfish containing excess levels of algal toxins (Category 1) and live shellfish which have died in transit (Category 2).

The ABPR sets out conditions under which animal by-products can be processed and includes requirements for waste storage, cleaning, infrastructure, treatment parameters, transport, documentation etc. Premises wishing to engage with animal by-products must satisfy its requirements, which may vary according to the type of activity used. In the UK, premises wishing to process animal by-products generally require approval from the State Veterinary Service, along with planning permission and environmental controls.

Various controls apply to the use of animal proteins in animal feed. Council Decision 2000/766/EC on protection measures regarding transmissible spongiform encephalopathies (TSE's) and feeding of animal proteins prohibits the feeding of processed animal proteins to farmed animals kept, fattened or bred for the production of food. It does not apply to fishmeal for non-ruminant diets.

Commission Regulation 811/2003/EC on the intra species recycling ban for fish, the burial and burning of by-products and certain transitional measures, provides additional clarification of the ABPR. It provides a derogation to permit the feeding of fish with processed animal protein derived from the same species. However this is academic as it does not apply to feeding farmed fish with processed animal protein from farmed fish which is already voluntarily banned by the feed industry. The Regulation also permits the use of wild fish and by-products for the production of fish feeds or directly as a feed. There are handling and processing requirements associated with this.

2.2.3 Disposal on Land

The Environmental Protection Act 1990 prohibits the keeping, treatment or disposal of waste on land unless a waste management licence has been granted for the purpose. It also places a duty of care onto businesses to dispose of waste correctly via an authorised waste transport operator or by taking it directly to an authorised place of disposal. There are documentation requirements associated with this.

The Waste Management Licensing Regulations 1994, as amended, permit some waste materials to be exempt from licensing. These include the use of waste food, drink or material used in or resulting from the preparation of food and drink, on agricultural land. The materials may be used for land application purposes if they result in benefit to agriculture or ecological improvement. They must not endanger human health or harm the environment by: presenting a risk to water, air, soil, plants or animals; causing nuisance through noise or odours; or adversely affecting the countryside or places of special interest. These activities must be registered with the relevant regulator (Environment Agency in England & Wales, Scottish Environmental Protection Agency in Scotland and the Environment and Heritage Service in Northern Ireland). The requirements of other legislation applicable to the type of material (such as animal by-products legislation for seafood waste etc) will still apply.

The Landfill Tax Regulations became effective in 1996 and levy charges on waste deposited in landfill sites. The objectives of the tax are to encourage waste producers to minimise the volume of waste generated, reduce the amount deposited in landfills and to encourage recycling. A distinction is made between inactive/inert waste, which is currently taxed at a lower rate than other waste. The standard rate increases each year and is paid by landfill operators, who in turn pass the charges onto the users of the site. The tax does not include the costs of contracting a waste disposal company.

There are further restrictions on landfill. Under the ABPR, the burial and burning (including landfill) of untreated animal waste from processing and retailing facilities is prohibited. Treated waste of animal origin can only be put into a landfill site that is licensed for that purpose. There are exceptions to the rules including a temporary derogation to permit the landfill of former foodstuffs, which includes cooked shellfish, until 1st January 2006.

The EU Landfill Directive requires member states to reduce the quantities of biodegradable waste being disposed of to landfill to 35% of 1995 levels by 2020 at the very latest. The only way to achieve this is to encourage alternative disposal routes for all biodegradable materials. It is inevitable that landfill use will become increasingly restricted and waste disposal options that obtain value from waste, such as composting or incineration with energy recovery, will take its place. Local authorities across the UK are currently planning and developing alternative waste management facilities in response to the landfill directive. Although these are being developed at the moment, many more are expected to come on stream in 2-5 years.

Developers of new landfill sites face increasing controls from other regulations. New landfill sites will operate under an authorisation issued under the PPC Regulations 2000, which implements not only the Waste Framework Directive but also the Integrated Pollution Prevention and Control (IPPC) Directive.

The system of IPPC applies an integrated environmental approach to the regulation of certain industrial activities. This means that emissions to air, water (including discharges to sewer) and land, plus a range of other environmental effects, must be considered together. It also means that regulators must set permit conditions so as to achieve a high level of protection for the environment as a whole. These conditions are based on the use of the “Best Available Techniques” (BAT), which balances the costs to the operator against the benefits to the environment. IPPC aims to prevent emissions and waste production and where that is not practicable, reduce them to acceptable levels. IPPC also takes the integrated approach beyond the initial task of permitting, through to the restoration of sites when industrial activities cease.

2.2.4 Disposal at Sea

The Food and Environment Protection Act 1985 controls the disposal of waste at sea through strict licensing. Most forms of disposal at sea were prohibited by the UK Government by the end of 1998. There are a few exemptions from licence control which are set out in the Deposits in the Sea (Exemptions) Order 1985. This Order permits a number of unlicensed exemptions for waste disposal from vessels or marine structures including waste arising from catching, handling and processing fish and shellfish at sea. A vessel is still allowed to dispose of that material even after landing its catch. However, the disposal at sea of waste from processing on-shore or waste that has been landed or transferred to a second vessel is not permitted without a licence.

3. The current situation for seafood waste production, treatment, utilisation and disposal

To assess the current situation regarding seafood waste treatment, utilisation and disposal, an industry survey was carried out by Seafish between November and December 2004 (Ref 6).

The survey involved asking the processing industry about the types and quantities of seafood waste produced and how it is currently utilised or disposed of.

The information was collected from a standardised telephone survey of 160 sea fish processing companies, chosen at random from both the shellfish and finfish sectors located throughout Scotland, England and Northern Ireland. This represented 30% of the UK seafood processing industry. The results of the survey were extrapolated to provide an estimate for each geographical region. Following consultation with industry, these figures were subsequently amended to provide more accurate estimations.

This section summarises the findings of this survey in terms of the finfish industry (section 3.1) and the shellfish industry (section 3.2). The survey does not take account of any seafood waste produced by port auction markets, retail and catering facilities.

The survey identified that approximately 312,875 tonnes of seafood processing waste is produced each year in the UK. Approximately 80% (249,950 tonnes) of this is finfish waste whereas 20% (62,925 tonnes) is shellfish.

Other surveys of seafood waste have been carried out by industry organisations and regulatory agencies but these largely cover only Scotland or specific regions (Refs 7, 8, 9).

3.1 The finfish sector

The estimated quantities of finfish waste produced by region are shown in Table 2 and Figure 1. The current routes, costs and revenue associated with finfish waste utilisation and disposal are shown in Table 3.

Table 2 The estimated quantity of finfish waste produced by region and as a proportion of total UK finfish waste production

Area	Total Tonnage	Proportion of total UK finfish waste
North East Scotland	140,000*	56%
Humber region (Hull & Grimsby)	50,000*	20%
Highlands & Islands	38,625	15.5%
Central Scotland	12,070	4.8%
North West England	3,200	1.3%
South West England	1,995	0.8%
Eastern England	1,700	0.7%
North East England	1,360	0.5%
Northern Ireland	600	0.2%
South West Scotland	250	0.1%
Southern England	150	<0.1%
Total	**249,950**	**100%**

* Figures provided by United Fish Products

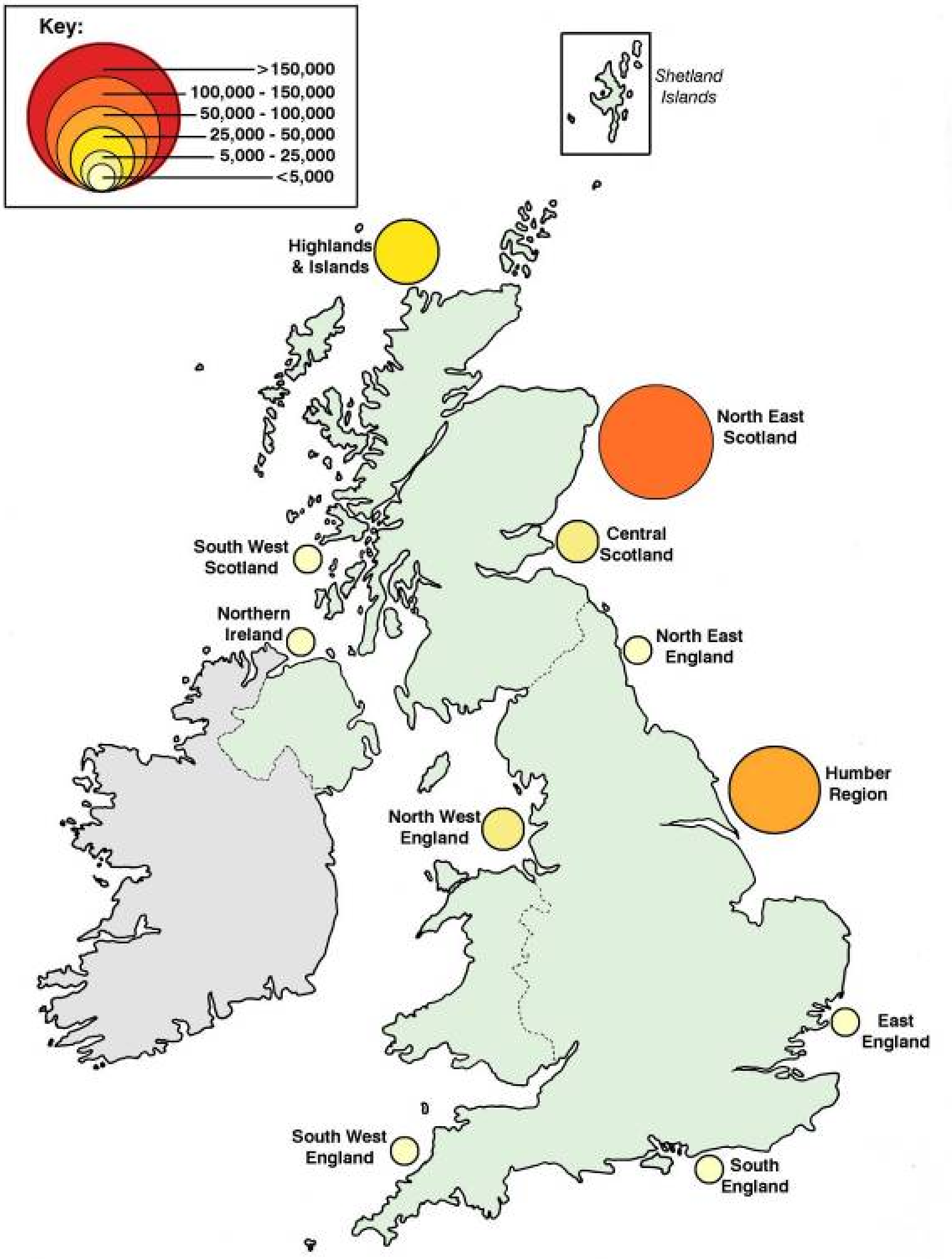

Figure 1 The quantity of finfish waste produced by region

Table 3 The current routes, estimated costs and revenue associated with finfish waste utilisation and disposal

Area	Total Tonnage	Waste utilisation or disposal routes	Disposal costs		Income	
			Ave Cost per tonne	Total Annual Cost	Ave revenue per tonne	Total annual revenue
Regions where majority of waste incurs disposal costs						
Highlands & Islands	38,625	Fishmeal - 45% others - 55%	£70	£1.5m	£14	£245,000
Eastern England	1,700	fishmeal - 40%	£35	£59,500	Nil	Nil
South West England	1,995	Landfill - 60%	£28	£55,860	Nil	Nil
Northern Ireland	600	60% to fishmeal	£100	£24,000	£10	£3,600
Southern England	150	Landfill	£38	£5,700	Nil	Nil
South West Scotland	250	Collected by local company	£20	£5,000	Nil	Nil
North East England	1,360	Fishmeal - 60%	£32	£17,400	£12.50	£10,200
Regions where majority of waste earns revenue						
North East Scotland	140,000	Fishmeal - 99%	Nil	Nil	£26	£3.64m
Humber region (Hull & Grimsby)	50,000	Fishmeal Animal feed	Nil	Nil	£28	£1.4m
North West England	3,200	Fishmeal - 90%	£25	£8,000	£20	£57,600
Central Scotland	12,070	55% to fishmeal	£33	£179,000	£27	£181,000
Total	**249,950**		**£42.33**	**£1.85m**	**£19.64**	**£5.54m**

Processors located in the Humber region, NE and NW England and NW Scotland did not seem concerned about the future for waste utilisation or disposal providing they still had access to the existing routes which generate income. However 20-35% of the processing sector in Central Scotland and Northern Ireland, and over 75% of processors elsewhere were concerned about the future for finfish waste utilisation and disposal.

3.2 The shellfish sector

The estimated quantities of shellfish waste produced are shown in Table 4 and Figure 2. The current routes, costs and revenue associated with shellfish waste utilisation and disposal are included in Table 5.

Table 4 The estimated quantity of shellfish waste produced by region and as a proportion of total UK shellfish waste production

Area	Main types of shellfish waste produced	Total Tonnage	Proportion of total UK shellfish waste produced
South West Scotland	*Nephrops and* Scallop	11,500	18.3%
Eastern England	Cockle & Crustacea	10,550*	16.8%
Northern Ireland	*Nephrops*	10,215	16.2%
Central Scotland	*Nephrops*	10,000	15.9%
South West England	Crustacea	8,385	13.3%
North East Scotland	*Nephrops*	3,900	6.2%
Highlands & Islands	*Nephrops* and Scallops	3,730	5.9%
North West England	Scallop and Whelk	3,200	5.1%
North East England	Crustacea	815	1.3%
Southern England	Crustacea	380	0.6%
Humber region (Hull & Grimsby)	Crustacea	250	0.4%
Total		**62,925**	**100%**

*includes seasonal cockle fishery closed at the time of the survey so estimated using catch data from 2003 and waste ratio of 85%

Table 5 The current routes and estimated costs of shellfish waste disposal

Area	Total Tonnage	Main disposal routes	Average disposal cost per tonne	Total annual cost
Eastern England	10,550	landfill - 80%	£66	£696,300
Central Scotland	10,000	landfill - 90%	£65	£650,000
Northern Ireland	10,215	Various	£55 – £100*	£562,000
South West England	8,385	Landfill - 60%	£40	£335,400
Highlands & Islands	3,730	Various	£47	£175,310
South West Scotland	11,500	Collected by local company	£10	£115,000
North West England	3,200	landfill - 55%	£48	£84,500
North East Scotland	3,900	landfill and disposal at sea 70%	£13	£50,700
North East England	815	Landfill - 80%	£44	£35,860
Humber region (Hull & Grimsby)	250	Landfill	£100	£25,000
Southern England	380	landfill - 90%	£37	£14,060
Total	**62,925**		**£41**	**£2,744,130**

* seasonal variation

The survey indicated that the shellfish industry largely pays to dispose of its waste through a number of routes. Landfill is the major route for shellfish waste disposal in the majority of regions. Over 80% of shellfish processors in all regions expect the situation to get worse when landfill is no longer available, and they expect costs to rise significantly.

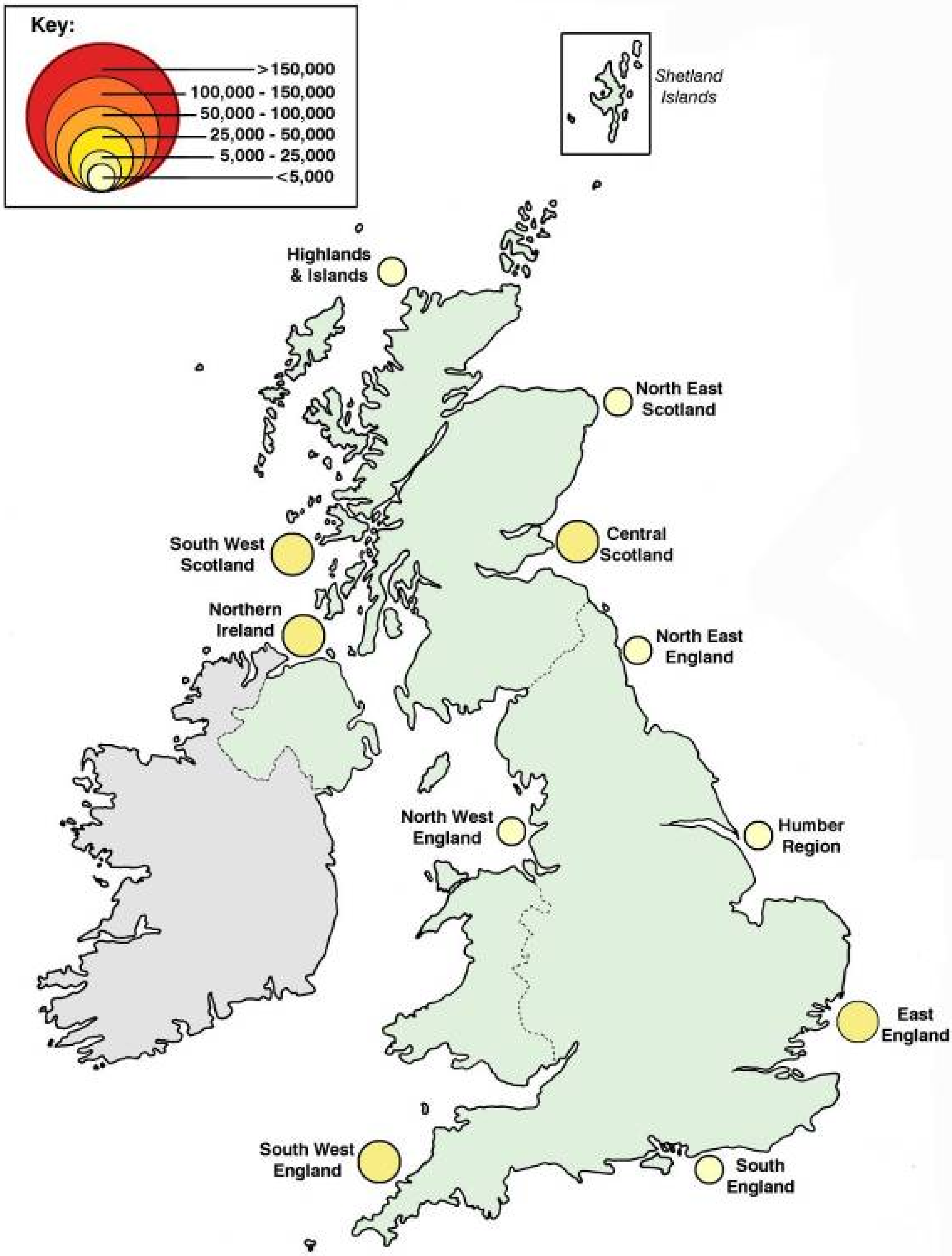

Figure 2 The quantity of shellfish waste produced by region

3.3 Main issues associated with the current seafood waste situation

The hub of the finfish processing sector is well served by the fishmeal processing factories in the Shetlands, NE Scotland and the Humber region (Hull and Grimsby). Other regions including NE and NW England, Central Scotland and parts of the Highlands & Islands also supply the fishmeal facilities. Processors with access to these facilities can generate an income for their waste. Approximately £5.5m annually is generated from the sale of finfish waste in this way.

Where access to the fishmeal factories is more difficult then the finfish processors either have to pay to collate and transport material to the fishmeal plants or pay for its disposal as waste. These areas include parts of Highlands & Islands, Eastern, Southern and South-west England, parts of Northern Ireland and SW Scotland. At present, processors in these areas pay approximately £1.65 million each year for seafood waste disposal. These processors believe they will encounter further difficulties in future and costs will increase.

The fishmeal factories and other companies that currently pay processors for finfish waste, have the capacity to process all of the finfish waste currently being generated in regions that currently pay for disposal. The finfish waste problem could therefore be addressed in these regions by establishing a co-operative collection and transportation service, which would take seafood waste to the nearest facility. This would take some organisation but has been successful in NW and NE England, although the income generated by selling such finfish waste is reduced by the transport and handling costs. However, this is preferable to disposal costs.

A far greater waste disposal problem exists in the shellfish processing sector where fishmeal and other such paying routes are not available. In all the regions there is a reliance on disposal routes, particularly landfill. The current cost to the shellfish industry is estimated at over £2.7 million each year, which is expected to rise significantly from January 2006 when landfill will no longer be permitted for untreated shellfish.

The survey also revealed that shellfish processors across the whole UK have few disposal options available to them. The few approved waste management facilities currently available can be expensive and located some distance from shellfish processors, incurring additional transport costs and logistical difficulties.

Overall, over 80% of shellfish processors are very concerned about how they will be able to dispose of their waste in future and the cost implications for their businesses.

In the long term, because of the need to develop facilities in response to the Landfill Directive, the commercial waste management industry will develop widespread infrastructure for managing waste. However these are not expected to be widely available to industry within 2-5 years.

In areas where this is the case, there is potential to develop either individual or regional cost-effective, shellfish waste management solutions, however, it appears highly unlikely that these will be available from 1st January 2006. It will take concerted effort to rectify this situation in the timescale available. As such, there may be a need to develop short-term interim solutions to address these problems in the shellfish sector. This will allow time for longer-term solutions and further developments by the commercial waste management industry to be put into place.

4. Consideration of seafood waste management options

In order to develop an overall strategic plan for the way forward, each seafood waste management option was assessed for its suitability, practicality and wider environmental impact. This assessment is based on the process of identifying the Best Practicable Environmental Option (BPEO) for the waste (see section 2.1). Within this are many factors to consider including social, economic, environmental, land use and resource use impacts. Undertaking BPEO effectively is a very detailed process, which can take a significant amount of time.

To undertake this assessment for seafood waste, a review of the different options for managing seafood waste, both traditional and new, was carried out using reference books, literature searches and by consulting directly with industry. During this process, it became apparent that much of the required information, such as costs, is currently unavailable. Where necessary, judgement has been used to compare and contrast the different seafood waste management options. As such, this assessment cannot be classed as a true BPEO for the management of seafood waste. However it does form a part of the basis for the strategic framework, which will help to resolve the current difficulties for seafood waste disposal and help industry move towards development of BPEO.

This section of the report summarises the findings of this assessment. Section 4.1 outlines the main options available and how they tie in with the waste hierarchy. Section 4.2 summarises the practicality and environmental impacts of the different options, whereas Section 4.3 brings the findings of these together to provide a ranked list of seafood waste management options.

4.1 Seafood waste management options within the waste hierarchy

There are many potential options for seafood waste management. The main routes, categorised according to the waste hierarchy, are shown in Table 6.

Reducing waste at source is at the top of the waste minimisation hierarchy and is considered a priority for businesses. In the seafood industry, reducing waste involves removing as much of the edible portion as possible to maximise the value of the raw material. Industry already removes the maximum part of the seafood that is traditionally eaten, however, there are options for utilising other parts of the fish or shellfish that are currently not commonly or directly eaten in the UK. These processes are outwith waste management controls as they remain products destined for human consumption. Most of these options are available to the finfish industry with fewer opportunities for increasing yield from some types of shellfish.

Re-use is considered as using products and materials again, for the same or a different purpose. An example of using a product again in the seafood industry is seen in the use of re-usable plastic fish-boxes compared to one-trip disposable boxes. An example of finding alternative uses for used products, which would otherwise be discarded, includes sending wooden pallets to a company that wishes to refurbish or re-use them. No options for directly reusing seafood waste have been identified.

The majority of seafood waste management options fall into the recovery/recycling category, which involve gaining value from waste by transforming it into different products. There are many products that can be made from recycled seafood waste, some of which are available for all types of seafood whilst others are limited to specific types.

Gaining value from waste includes energy recovery. Energy can be recovered from seafood waste in a number of ways but its suitability for some types, particularly shellfish, is unknown.

Waste disposal at the bottom of the waste hierarchy and includes options where no perceived value is derived.

Table 6 The main seafood waste management options within the waste hierarchy

		Waste management option
Reduce		Heads, tongues, cheeks, fins Mince Roe & milt Soup, stocks, sauces
Recycle	All seafood	Fishmeal and oil Ensiling (excluding heat treatment) Rendering Composting Aerobic digestion Mechanical and biological treatment Autoclaving Alkaline hydrolysis Direct animal feeding (particularly bait) Fertilisers and soil conditioners Landspreading (excluding initial treatment) Pharmaceuticals & cosmetics
	Finfish only	Fish bones Collagen & gelatine Fish protein concentrates Fish protein hydrolysates Enzymes Leather
	Shellfish only	Crustacea based derivatives including chitin, chitosan and pigments Mollusc shell based products including aggregates, paths, land drainage, garden products, ornamental use Cultch
Energy recovery from waste		Anaerobic digestion Incineration with energy recovery Biofuels
Disposal		Disposal at sea Incineration

4.2 Assessment of the different options for seafood waste management

To identify the potential feasibility of establishing dedicated seafood waste management facilities, each option was reviewed in detail. This review included an evaluation of the process, level of technology required, complexity, legality, scale, costs, whether marketable products are produced and a SWOT analysis, see Appendix I. An approximation of the timescales involved in establishing facilities was also included, although these are more subjective as they depend on scale, complexity, whether existing premises are used, planning procedures, obtaining necessary permissions etc. The results of the detailed review were used to summarise the main requirements for each option (Table 7).

In terms of practicality, it is desirable to have waste management options that are legally permitted, cost effective, readily available in a short timescale, suitable for a range of throughputs, and result in either no waste or a useful product. There should also be advantages that outweigh any negatives.

It is apparent that some options, such as those that can be carried out locally or within an existing processing operation, are potentially feasible to establish within a short timeframe as they satisfy these criteria. These include edible products such as mince and heads, direct animal feeding (bait), tying in with the established infrastructure (for fishmeal and other income generating streams), landspreading, shell based products, cultch and disposal at sea.

Although other options appear feasible, they are considerably more complicated to establish. For example, composting and aerobic digestion are well known technologies which could be carried out on either an individual or regional basis but would take some time to establish. It is not uncommon for a waste management facility to take two years to establish because of the complexities of licensing and planning rules, although there are exceptions to this.

Other options are also well known but only appear feasible on a larger scale. These include rendering, fishmeal, alkaline hydrolysis, fertilisers, incineration and anaerobic digestion. In these cases, regions would have to assess these options separately in order to identify whether enough seafood waste is produced to justify seafood waste treatment facilities on this scale.

Options including crustacea based derivatives, fish protein hydrolysate, fish protein concentrate, enzymes, leather, fertilisers, collagen, gelatine, biofuels and pharmaceuticals are highly specialised with potential for producing valuable products. However there are many more uncertainties about these options including technical feasibility, scale, markets, costs, logistics and raw material availability. These required detailed feasibility studies before actual decisions about their feasibility and how they tie in with the BPEO framework can be made.

Table 7 Comparison of the practicality of different seafood waste management options

Waste management option		Is it legal	Costs: Capital cost	Costs: Cost per tonne	End uses: Produces a marketable product?	End uses: Readily available markets?	Minimum throughput or scale of facility required	Minimum scope of facility	Estimated timescale to establish this option
		yes or no	low, med, high		yes, no, needs investigation, niche (requires special process approach)		small, medium, large	local, regional, national	0-1, 1-2, 2-3, 3+ years
Reduce	**Heads, tongues, cheeks, fins**	yes	low	low	yes	Niche	small	local	0-1
	Mince	yes	low	low	yes	Niche	small	local	0-1
	Roe & milt	yes	low	med	yes	Niche	medium	local	0-1
	Soup, stocks, sauces	yes	low	med	yes	Niche	medium	local-regional	1-2
Recycle	**Fishmeal and oil**	yes	high	high	yes	Yes	large	national	1-2
	Ensiling (excluding heat treatment)	yes	med	low	No	No	small	regional	0-1
	Rendering	yes	high	high	Needs investigation	Needs investigation	large	regional	2-3
	Composting	yes	med-high	med	Yes	Yes	medium	regional	2-3
	Aerobic digestion	yes	high	high	Yes	Yes	medium	regional	2-3
	Mechanical and biological treatment	yes	high	high	Needs investigation	Needs investigation	medium	local/regional	2-3
All seafood	**Autoclaving**	yes	high	high	Needs investigation	Needs investigation	small	local/regional	1-2
	Alkaline hydrolysis	yes	high	high	Needs investigation	Needs investigation	large	regional-national	3+
	Direct animal feeding (bait)	yes	low	low	Yes	Yes	small	local	0-1
	Fertilisers and soil conditioners	yes	high	high	Yes	Yes	large	regional	2-3

Waste management option		Is it legal	Costs		End uses		Minimum throughput or scale of facility required	Minimum scope of facility	Availability of this option
			Capital cost	Cost per tonne	Produces a marketable product?	Readily available markets?			
		yes or no	low, med, high		yes, no, needs investigation		small, medium, large	local, regional, national	0-1, 1-2, 2-3, 3+ years
	Landspreading (excluding initial treatment)	yes	low	low	Yes	Yes	small	local	0-1
	Pharmaceuticals & cosmetics	yes	high	high	Yes	Needs investigation	large	national	3+
Recycle Finfish only	**Fish bones**	yes	low	low-med	Yes	Yes	medium	regional	1-2
	Collagen & gelatine	yes	high	high	Yes	Needs investigation	large	national	2-3
	Fish protein concentrates	yes	high	high	Yes	Needs investigation	large	national	3+
	Fish protein hydrolysates	yes	high	high	Yes	Needs investigation	large	national	3+
	Enzymes	yes	high	high	Yes	Needs investigation	large	national	3+
	Leather	yes	med-high	high	Yes	Needs investigation	large	regional-national	2-3
Recycle Shellfish only	**Crustacea based derivatives**	yes	high	high	Yes	Yes	large	regional-national	3+
	Mollusc shell based products	yes	low	med	Yes	Yes	small	local-regional	0-1
	Cultch	yes	low	low	No	No	small	local	0-1
Energy recovery from waste	**Anaerobic digestion**	yes	high	med	Yes	Yes	large	regional-national	3+
	Incineration with energy recovery	yes	high	high	Yes	Yes	large	regional-national	3+
	Biofuels	yes	high	high	Yes	Yes	large	regional-national	3+
Disposal	**Disposal at sea**	yes	medium	low	No	No	small	local-regional	0-1
	Incineration	yes	high	high	No	No	large	regional-national	3+

4.2.1 Environmental impacts

Each option for seafood waste management was also evaluated for its environmental impact. With the limited time and information available, a very simple comparative review was carried out.

Each option was assessed for its impact on noise, odour, transport miles, solid and liquid waste production, energy and water use, space requirements and airborne pollution. No account was taken of any remediation measures. For simplicity, each answer was scored 0 to 2, with 0 classed as the lowest impact. A total score for each option is out of 16, with a higher score suggesting a higher environmental impact (Table 8).

This very simplistic approach is not without problems. For example, higher scores suggest a higher environmental impact, however, in reality these options are required to invest heavily in measures to reduce these impacts. Therefore it may be more valid to suggest that the options with a higher score, although they potentially have a significant environmental impact, would require substantial investment to counteract those impacts.

Overall the scores can be simplified to four main groups; 1-4, 5-8, 9-12 and 13-16 which rank the options, in order of the scale of their potential environmental impact (Table 9).

Table 8 Environmental impact comparison of each seafood waste management option

Waste Utilisation or disposal option		Odour (yes=1, no=0)	Noise (low=0, medium=1, high=2)	Transport (local=1, regional=2, national =3)	Solid waste (yes=1, no=0)	Airborne pollution (yes=1, no=0)	Energy use (low=0, medium=1, high=2)	Water Use (low=0, medium=1, high=2)	Liquid waste (low=0, medium=1, high=2)	Space requirements (low=0, medium=1, high=2)	Total score
Reduce	**Heads, tongues / cheeks / fins**	0	0	1	1	0	0	0	1	0	**3**
	Mince	0	0	1	1	0	0	0	1	0	**3**
	Roe & milt	0	0	1	1	0	0	0	1	0	**3**
	Soup, stocks, sauces	1	0	2	1	1	1	1	1	1	**9**
Recycle All seafood waste	**Fishmeal and oil**	1	1	3	0	1	2	1	2	2	**13**
	Ensiling (excluding heat treatment)	1	1	2	0	0	0	0	0	1	**5**
	Rendering	1	1	2	1	1	2	1	2	2	**13**
	Composting	1	1	2	0	1	1	0	2	2	**10**
	Aerobic digestion	1	0	2	0	1	2	2	0	2	**10**
	Mechanical and biological treatment	1	2	2	1	1	2	1	2	2	**14**
	Autoclaving	1	2	2	1	1	2	1	2	2	**14**
	Alkaline hydrolysis	1	1	3	0	1	2	2	1	2	**13**
	Direct animal feed (particularly bait)	0	0	1	0	0	0	0	0	0	**1**
	Fertilisers and soil conditioners	1	1	2	0	1	1	1	1	1	**9**
	Landspreading	1	0	1	0	0	0	0	1	2	**5**
	Pharmaceuticals & cosmetics	1	1	3	1	1	2	2	1	2	**14**
Finfish only	**Fish bones**	1	1	3	1	1	1	1	1	1	**11**
	Collagen & gelatine	1	1	3	1	1	2	2	2	1	**14**
	Protein concentrates	1	1	3	1	1	2	1	1	2	**13**
	Fish protein hydrolysates	1	1	3	1	1	2	1	1	2	**13**
	Enzymes	1	1	3	1	1	2	1	1	2	**13**
	Leather	1	1	3	1	1	2	2	2	2	**15**
Shellfish only	**Crustacea based derivatives**	1	1	3	1	1	2	1	2	2	**14**
	Molluscan shell based products	0	0	2	1	1	1	1	1	2	**9**
	Cultch	0	0	1	1	0	0	0	0	1	**3**
Energy recovery	**Anaerobic digestion**	1	1	3	0	1	1	0	0	2	**9**
	Incineration with energy recovery	1	2	3	1	1	2	0	0	2	**12**
	Biofuels	1	1	3	1	1	2	0	0	2	**11**
Disposal	**Disposal at sea**	0	0	1	0	0	0	0	0	1	**2**
	Incineration (no energy recovery)	1	2	3	1	1	2	0	0	2	**12**

Table 9 Overall environmental impact scores for the different seafood waste management options

Scores	Options
1 - 4	Heads, tongues, cheeks, fins Mince Roe and milt Direct animal feed Cultch Disposal at sea
5 - 8	Ensiling (excluding heat treatment) Landspreading
9 - 12	Soups, stocks and sauces Composting Aerobic digestion Anaerobic digestion Fertilisers and soil conditioners Fish bones Molluscan shell based products Incineration with energy recovery Biofuels
13 - 16	Fishmeal & oil Rendering Mechanical and biological treatment Autoclaving Alkaline hydrolysis Incineration Pharmaceuticals Collagen and gelatine Fish protein concentrates Fish protein hydrolysates Enzymes Leather Crustacea based derivatives

4.3 Waste management option summary

Considering the available information on the practicality and environmental impact of each option, a ranked list of the different waste management options was produced. The options are categorised according to the order of priority in which they could be developed in the short, medium or long-term (Table 10). Emphasis was placed on the practicality of the options because of the need to address immediate problems with shellfish waste disposal and develop alternatives to landfill.

The options were considered on the basis of establishing dedicated seafood waste treatment facilities. However, there are a number of companies that currently take seafood waste for different uses but which could possibly be made more widely available. These include fishmeal, and on a much smaller scale, pet foods, rendering composting and shell products. As these uses are already available, they have been included in this final list of options as 'existing uses'.

This generic review of each option cannot provide a definitive list of seafood waste management options to adopt in different regions or individual companies. However it provides a basis on which to establish future decision making.

Table 10 Seafood waste management options in order of their prioritised timescale

Timescale	Waste management option
Short-term	Use of existing infrastructure (where available) Development of infrastructure for existing uses including fishmeal, shell products, pet food, waste management businesses Heads, tongues, cheeks, fins Mince Roe and milt Ensiling (excluding heat treatment) Direct animal feeding (bait) Landspreading Molluscan shell based products Cultch Disposal at sea
Medium-term	Soups, stocks, sauces Autoclaving Mechanical and biological treatment (shell) Fish bones Crustacea based products
Long-term*	Fishmeal Rendering Composting Aerobic digestion Anaerobic digestion Alkaline hydrolysis Fertilisers and soil conditioners Pharmaceuticals and cosmetics Collagen and gelatine Fish protein concentrate Fish protein hydrolysate Enzymes Leather Incineration (with or without energy recovery) Biofuels

*establishing dedicated seafood waste treatment facilities

It is evident that further effort should initially focus on the short and medium term priorities as these could help to increase the possible routes for seafood waste within a reasonable timescale. For the finfish sector this should largely focus on developing co-operative collection routes, to tie in with the fishmeal (income generation) option which is preferable to paying for disposal. For the shellfish industry, this should involve tying in with existing solutions where available or the development of collaborative ventures to develop simple, cost-effective waste management routes. The longer-term options have not been ruled out but they need to be considered in more detail because of their particular complexities, as it is difficult to justify such considerable investment on the basis of the information available.

In reality some of the options, such as land application and disposal at sea, are not readily available because of complex but necessary licensing and application procedures designed to protect health and the environment. There are also examples of geographical differences, for example some regions permit land application of treated shell, whereas others do not. As such, the options listed as short-term may not be available to all regions across the UK.

All the options require detailed assessment before decisions can be made about their feasibility for a region or company. In general this includes more specific assessment of legalities, potential markets for any products produced, identification of actual costs, infrastructure requirements and longevity. Appendix II includes a brief summary of the actions that need to be taken for each option.

5. Strategic framework

An effective strategic framework is essential to resolve current problems with seafood waste disposal and ultimately move the industry towards better utilisation of the overall seafood resource. This section is concerned with the development of this strategic framework. It includes the strategic aims and objectives and provides a gap analysis which was produced using the findings of Sections 2, 3 and 4. Using these as a basis, a set of prioritised action plans for the short, medium and long term are included.

The framework sets out a 10-year strategic vision for waste management in the seafood industry.

5.1. Strategic aims and objectives

The strategic vision for managing waste in the seafood industry is to ensure compliance with relevant legislation and maximise the economic value of the seafood resource.

To achieve this vision, the framework was developed using the following three aims which are prioritised in order of necessity or desirability, with the most important first.

Aim 1. All companies comply with relevant legislation (necessary minimum required)

Aim 2. Generate economic return from waste material (desirable)

Aim 3. Generate significant and profitable returns from waste material (ideal)

The relationship between these aims and the strategic vision is illustrated in Figure 3. The size of the pyramid sections reflects the diminishing number of companies who are expected to achieve the increasingly ambitious aims.

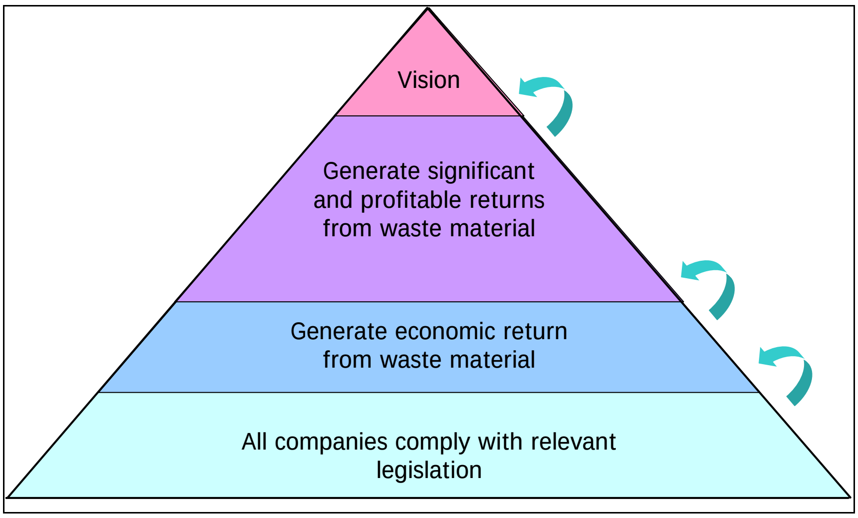

Figure 3 Hierarchy of aims

In order to meet these aims, specific objectives were assigned to each, along with an estimated timescale

Aim 1. All companies comply with relevant legislation (minimum required)

Objective 1.1 All companies to be aware of legal requirements by end August 2005.

Objective 1.2 All companies to be legally compliant by January 2007.

Aim 2. Generate economic return from waste material (desirable)

Objective 2.1 - Target groups to be aware of routes to market that generate a return for waste by April 2007

Objective 2.2 - Companies in target groups to generate economic return from waste by 2010.

Aim 3. Generate significant and profitable returns from waste material (ideal)

Objective 3.1 - Target groups to be aware of routes to market that generate profitable returns for waste by June 2008

Objective 3.2 - Companies in target groups to generate profit from waste by 2015.

This is summarised in the strategy timetable below (Table 11).

Table 11 Strategy timetable

	Timetable										
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Aim 1. Compliance											
Aware of legal requirements	■										
All compliant		■									
Aim 2. Economic return											
Aware of relevant options		■	■								
Target groups generating a return			■	■	■	■					
Aim 3. Profitable return											
Aware of relevant options			■	■							
Target groups generating a profitable return				■	■	■	■	■	■	■	■
Monitoring	■	■	■	■	■	■	■	■	■	■	■

Based on this timetable, achieving compliance is the short-term aim whereas generating economic or profitable returns are, respectively, medium to long-term aims.

5.2 Gap analysis and prioritisation by sector and geographical region

The position of individual seafood companies in the hierarchy of aims will differ. Some companies may be unable to meet legal requirements, whilst others may already be making a financial return on the waste they produce. The ability of seafood companies to meet legal requirements, make a return or significant profit will depend on many factors such as industry sector, geographical location, availability of infrastructure, cost-effectiveness, progressiveness etc.

The gap analysis (Table 12) highlights the geographical groups currently failing to meet the three specific strategic aims. Shading shows those regions that are already fulfilling that aim. The analysis is based on the information contained in sections two, three and four.

Table 12 Summary gap analysis

Strategic aims	Seafood sector and geographical region	
	Finfish	**Shellfish**
Aim 1: *All companies comply with relevant legislation (minimum required)* *Short-term 2005-2007*	*Highlands & Islands* *Eastern England* *Northern Ireland* *Southern England* *SW Scotland* *Humber region* *NE Scotland* *Central Scotland* *NW England* *NE England* *SW England*	*Central Scotland* *Northern Ireland* *SW England* *NE Scotland* *Highlands & Islands* *SW Scotland* *NW England* *Eastern England* *NE England* *Humber region* *Southern England*
Aim 2: *Generate economic return from waste material (desirable)* *Medium term 2006-2010*	*Highlands & Islands* *Eastern England* *SW England* *Northern Ireland* *Southern England* *SW Scotland* *Humber region* *NE Scotland* *Central Scotland* *NW England* *NE England*	*Central Scotland* *Northern Ireland* *SW England* *NE Scotland* *Highlands & Islands* *SW Scotland* *NW England* *Eastern England* *NE England* *Humber region* *Southern England*
Aim 3: *Generate significant and profitable returns from waste material (ideal)* *Long-term 2006-2015*	*Central Scotland* *Northern Ireland* *NE Scotland* *SW England* *Highlands & islands* *SW Scotland* *NW England* *Eastern England* *NE England* *Humber region* *Southern England*	*Central Scotland* *Northern Ireland* *SW England* *NE Scotland* *Highlands & islands* *SW Scotland* *NW England* *Eastern England* *NE England* *Humber region* *Southern England*

Scarce resources (money and time) means seafood waste support actions must be targeted to ensure the aims and objectives of the strategy are achieved. The gap analysis shows the sectors and geographical areas that ought to be prioritised for attention. For each aim, these include;

Aim 1 – All companies comply with relevant legislation
The gap analysis indicates that the specific target groups are shellfish processors in all regions of the UK and finfish processors in Highlands & Islands, Eastern England, Northern Ireland, Southern England and SW Scotland.

Aim 2 – Generate economic return from waste material

Specific target groups to prioritise are shellfish processors in all regions of the UK and finfish processors in the Highlands & Islands of Scotland, Eastern England, Northern Ireland, Southern England, SW England and SW Scotland.

Aim 3 – Generate significant and profitable returns from waste material
Potentially applicable to all the seafood industry in all regions.

5.3 From ambition to action

Three overall action plans, based on the strategic aims, were then developed to help industry work towards more sustainable seafood waste management. These cover the next ten years and provide a methodical approach to addressing the issues.

The plans provide detailed action points where these can be identified (at this stage restricted to Seafish activities). Detailed action points for other stakeholders have not been identified at this stage given the many uncertainties and the desire to avoid a prescriptive approach[1]. Instead a timetable with suggested action points and milestones have been set out for other stakeholders, concerning their own specific regional action planning and implementation process.

To assist with this, an action planning 'toolbox' approach is advocated. Essentially this is a structured process that would help generate specific regional action plans. This specifically contains the following more in-depth questions:

- What barriers to exist?
- What options are available?
- What are the feasible solutions?
- What actions should take place, when, how, by whom and at what cost?

This is assisted by the information on legislative requirements, current waste practice and waste management options contained within this report. It is envisaged that Seafish will facilitate the development of these action plans in the key regions, using this overall action planning toolbox approach as a basis.

Section 5.3.1 outlines the action plan for the period 2005-2007 which will enable industry to achieve legal compliance. Sections 5.3.2 and 5.3.3 cover the periods 2005-2010 (economic return) and 2007-2015 (profitable return) respectively.

5.3.1 Action plan for enabling all companies to comply with relevant legislation (Aim 1)

A short-term action plan for the next two years was developed (Table 13). This details the required action points to achieve each strategic objective within the overall aim.

The generic approach (Table 13) includes the immediate priorities, such as raising awareness, which includes a number of tasks such as developing informative newsletters and promotional materials. Following on from this, enabling all companies to be compliant involves a number of distinct stages. These include establishing collaborative groups in the key target regions (from Table 12), developing and delivering a toolkit of solutions and developing projects to facilitate compliance. Each stage is further broken down into a series of steps that should be undertaken in order to allow the next stage to be completed.

Regional action plans
The initial emphasis for delivery of solutions is to establish collaborative groups in key target regions to develop and deliver a targeted action plan for the region. At this stage it is not

[1] For example, the way forward is largely based on establishing collaborative groups in key target regions but there are uncertainties surrounding the context of each group and who will lead, develop and implement their action plans

appropriate to be too specific about how these groups should operate but a suggested action plan, which gives a framework on which to base the way forward, is included in Appendix III.

Seafish will take the lead in establishing regional groups and assisting with the provision of information and development of regional plans. Financial support for establishing these groups will be required and may be available through the Financial Instruments for Fisheries Guidance (FIFG) scheme, which Seafish can help to access.

Although Seafish will also assist in the delivery of the regional action plans, it is envisaged that people within the groups will take a more active role as they are better placed to develop and implement regional solutions. Each group will identify suitable people or organisations that could take the lead.

In terms of assessing the options for achieving compliance, it is evident that this should focus on short-term, readily available options or those that require only limited development. This will largely include using existing waste management companies and solution providers, or using knowledge gained from experiences of seafood businesses, industry organisations and other regional groups. Appendix II gives an overview of the level of activities required for each of the seafood waste management options considered to be available in the short-term. Further effort will be required to develop suitable handling and storage facilities.

There is a possibility that co-operative ventures will be formed to help businesses establish waste treatment facilities in the key target regions. Seafish will also provide input to this process including helping to access funding.

5.3.2 Action plan for enabling companies to generate economic return from waste (Aim 2)

A medium term action plan covering the period 2005-2010 has been developed (Table 14). This outlines the action points required to achieve the strategic objectives within the overall aim. There are many more uncertainties in this aim, with no guarantees of success. However, this action plan provides a framework on which collaborative groups can evaluate the different options available to them, and assess their relative feasibility for their situations.

The majority of the finfish sector is already meeting this aim, benefiting from an income generation route (fishmeal). As such it is expected that most of these companies would stop at this level. Conversely in the shellfish sector, which has few if any income generation routes, this Aim is significantly more difficult to achieve, requiring a considerable concerted effort. As such there will be fewer companies who are interested in or who can achieve this aim.

Despite this, it is important to initially promote awareness of the routes that can generate economic return and establish collaborative groups in key regions. However, there will be fewer groups than previous, or the group may comprise different people, reflecting the key target waste streams. In order to develop economic return it will be necessary for collaborative groups to engage, to improve chances of developing a successful solution.

Seafish will support regional groups to help achieve this overall aim but it is envisaged that the groups will take a more active role. There will be a need to assess some of the options on a more detailed level, possibly requiring some further research and higher level of resources. This will obviously takes time to complete, hence the longer timescale to deliver these solutions.

Appendix II gives an overview of the level of activities required for each of the medium-term seafood waste management options. Further effort will be required to develop suitable handling and storage facilities.

5.3.3 Action plan for enabling companies to generate significant profitable return from waste (Aim 3)

The longer-term action plan covering the period 2007-2015 is shown in Table 15. This outlines the action points required to achieve the strategic objectives within the overall aim. The action plan gives the overall approach that should be followed in order to make informed decisions. Seafish will support regional groups to help achieve this aim but it is envisaged that the groups will take a more active role in leading this work.

Many companies will find it difficult if not impossible to achieve this aim but there is merit in evaluating the options in some regions. As such, it is important to initially promote awareness of the routes that can generate profitable return and establish collaborative groups in key regions. However there will be fewer groups than previous, or the group may comprise different people, be based on a national waste stream, to reflect key waste streams which have greater chance of generating profitable returns.

For all the options which could generate a profitable return, there will be a considerable amount of further assessment required necessitating further research, evaluation of markets, cost-benefits, handling, storage, infrastructure and logistical requirements etc. These could take a long time to complete but are necessary given that the generation of profits will require the development of a dedicated seafood waste management business. Regional groups will need to be sure that the solutions achieve their objectives, requiring a sound basis on which to make these decisions. At the moment there are many gaps in this information which will need to be addressed. Appendix II gives an overview of the level of activities required for each of the longer term seafood waste management options.

Developing facilities to generate significant profitable return will be a more prolonged process with no guarantee of success. It will require a significant level of collaboration with relevant specialists and possibly other collaborative groups. It will require a much higher level of effort and resources to achieve.

5.4 Monitoring and review

There is a need to monitor progress of the overall strategy and whether the different action plans are allowing groups to achieve strategic aims. It will also help to identify any risks to the strategy and changes that are required to improve chances of success. Monitoring stages are included in the action plans. Seafish will monitor overall progress on an annual basis whilst collaborative groups should ensure that monitoring is included within their action plans.

Table 13 – Short-term action plan for all companies to achieve compliance by January 2007 (Aim 1)

	2005			2006				2007
	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec	Jan-Mar
Objective 1.1 Awareness of legal requirements								
Development of promotional material								
Preparation of material	■							
Ongoing awareness raising								
30 visits to key companies	■	■						
2 newsletters/circulars	■	■						
3 waste events held	■	■						
3 press releases	■	■						
Objective 1.2 All companies compliant								
Establish 8 collaborative groups								
Presentation to regional groups	■	■						
Identification of key/interested partners	■	■	■					
Develop & deliver action planning toolkit								
Assessment of regional situation including barriers		■	■					
Options appraisal		■	■					
Action plan produced		■	■	■				
Financial resources secured			■	■				
Compliance projects completed								
8 compliance projects completed			■	■	■	■	■	■
Monitoring								
Monitoring	■		■		■		■	

Table 14 – Medium term action plan for companies in key target regions to generate economic return by 2010 (Aim 2)

		2007		2008		2009		2010
	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun
Objective 2.1 Awareness of economic value options								
Development of promotional material								
Preparation of material	■							
Ongoing awareness raising								
20 visits to key companies within target areas	■	■	■					
4 newsletters/circulars to all companies within target region	■	■	■					
4 press releases	■	■	■					
Objective 2.2 Companies in target groups to generate economic return								
Establish 4 collaborative groups								
Identification of key/interested partners				■	■	■		
Develop & deliver action planning toolkit								
Assessment of latest regional situation			■					
Detailed appraisal of economic return options			■	■	■			
Action plan produced				■	■	■		
Financial resources secured					■	■		
Economic return projects completed								
4 economic return projects completed					■	■	■	■
Monitoring								
Monitoring	■		■		■		■	

Table 15 – Long-term action plan for companies in key target regions to generate significant and profitable return by 2015 (Aim 3)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec
Objective 3.1 Awareness of significant profitable return options									
Development of promotional material									
Preparation of material	■								
Ongoing awareness raising									
20 visits to key companies within target areas	■	■							
4 newsletters/circulars to all companies within target region	■	■							
4 press releases	■	■							
Objective 3.2 Companies in target groups to generate significant and profitable return									
Establish 2 collaborative groups									
Identification of key/interested partners		■	■						
Develop & deliver action planning toolkit									
Assessment of latest situation		■	■						
Detailed assessment of profitable return options			■	■					
Action plan produced				■	■				
Financial resources secured					■				
Economic significant profitable return projects completed									
2 significant profitable return projects completed					■	■	■	■	■
Monitoring									
Monitoring	■		■		■		■		■

6. Discussion

From the assessment of the current situation for seafood waste management, it is apparent that some regions of industry will struggle to comply with the ban on landfill of former foodstuffs from 1st January 2006. The shellfish industry in particular is expected to experience difficulties due to lack of awareness of the issues and a current lack of facilities that will take seafood waste. The finfish sector could resolve the problems more easily but will still require support to do so. As a minimum, ensuring compliance with legislation is imperative and so doing nothing to resolve this situation is clearly not an option. This strategic framework forms the basis of how industry can move forward to resolve the current problems, however, they will need to be supported and assisted through this process.

In the short-term, industry needs to develop contacts with existing solution providers and the commercial waste management industry to try to establish contracts for seafood waste management. Where these are unavailable, industry will need to consider alternative options available to them. For the shellfish industry, this will require investigation of short-term options such as land application. Other measures, such as disposal at sea, may be required in the interim, until such time when suitable waste management facilities are established.

The finfish industry, in the regions that currently pay for waste disposal, should consider developing regional collection schemes for transporting material to facilities that currently pay for waste which include fishmeal and pet food. Although a preferred and readily available option, this still require concerted effort in terms of developing hygienic storage and transport, logistics, maintenance of quality, management, licensing etc.

There is a need to establish regional collaborations to help develop and support these activities as soon as possible. This will lead to the development and implementation of specific regional action plans to address the issues on a collective basis, which may provide more cost-effective solutions. Regional groups will have to consider the different options available and what facilities are required.

In the medium and longer-term, industry should look at the range of options which generate economic return from waste, and ultimately aim towards generating profit from waste streams which can be recycled into valuable products. Although these are much more difficult to achieve with no guarantees of success, they could contribute towards a more sustainable future.

The development and delivery of the way forward requires commitment from Seafish, industry, devolved regional governments, environmental agencies, local authorities, funding agencies etc to help resolve problems and move forward. A considerable amount of information is available to signpost businesses to information that will help them find companies that may be able to treat waste. Similarly there are grants available that can be used to help companies develop their facilities. All this information needs to be collated and disseminated as widely and as soon as possible to initiate the process of change.

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APPENDIX I – Assessment of the different seafood waste management options

Reducing waste at source is at the top of the waste minimisation hierarchy and is considered a priority for businesses. In the seafood industry, reducing waste involves removing as much of the edible portion as possible to maximise the value of the raw material.

Reducing waste in the seafood industry largely involves developing a wider range of products for human consumption, rather than just the fish fillet for example. Products for human consumption fall outwith the scope of the animal by-product regulations, however, it necessitates that the material is initially collected, handled and stored to the same standards as other fishery products. This should not pose a problem as businesses are already geared up to meet these requirements.

Reducing waste often involves simple technical solutions requiring minimal capital investment. It is far better to maximise the use of the resource than to pay to purchase the raw material and pay further costs to dispose of any waste produced. The main product waste reduction options are covered in Section 1. There are other waste reduction methods available, such as dewatering (by use of centrifuge, presses or heat treatment), but these are usually a pre-treatment to other waste management processes. They can be effective are reducing the weight and volume (and hence disposal costs) of waste, but they do not provide a complete waste treatment process in their own right. Companies should be aware of these types of waste minimisation technologies in order to assess any potential cost-savings that may be derived from their use.

Re-use is considered as using products and materials again, for the same or a different purpose. An example of using a product again in the seafood industry is seen in the use of re-usable plastic fish-boxes compared to one-trip disposable boxes. An example of finding alternative uses for used products which would otherwise be discarded includes sending wooden pallets to a company that wishes to refurbish or re-use them. There are no re-use opportunities for seafood waste as they are either directly used in edible products or recycled to make other products.

Recovery and recycling involves gaining value from waste by transforming it into different products. There are many products that can be made from recycled seafood waste, some of which are available for all types whilst others are limited to specific types. The main opportunities for recycling are outlined in this section. Options for all seafood waste are included in section 2.1 whilst finfish and shellfish options are described respectively in sections 2.2 and 2.3.

Gaining value from waste also includes energy recovery. Energy can be recovered from seafood waste in a number of ways but its suitability for some types, particularly shellfish, is questionable. Energy recovery from waste is covered in section 3.

Waste disposal at the bottom of the waste hierarchy and includes options where no perceived value is derived. These are described in section 4.

1. Options for reducing waste

1.1 Tongues, Cheeks, Heads, Fins & Stomachs

Tongue and cheek flesh can be used in its own right or in the production of fish mince, pies, fishcakes and re-formed products. Tongues and fins from sharks and other cartilaginous species are sought after in Eastern countries for culinary and medicinal purposes. The tongues, cheeks and fins of large fish can be recovered either manually or mechanically. Tongues and cheeks are retailed in some parts of Europe at prices similar to fillets.

Salted and fermented cod heads are considered a delicacy in Nigeria. In Iceland, popular dishes include dried fish heads softened in dairy whey. Fish stomachs are considered a culinary delicacy in Iceland, Japan and other Eastern countries. Norwegian fishermen are encouraged to retain cod stomachs, which are collected centrally and then exported to Japan. The stomachs may also be partially hydrolysed to create 'changi' a dish with a characteristic flavour and texture or can be fully hydrolysed to make a highly prized sauce or stock.

Economics and costs

Removal of tongues and cheeks and stomachs by hand involves low capital costs, but is labour-intensive. Alternatively specialist processing equipment can be used.

Heading is typically carried out as part of the manual or automated filleting operation. Energy costs involved in drying heads can be substantial. In Iceland, drying systems incorporating an efficient heat pump can have reduced drying costs by 70% to about £20 per tonne

SWOT analysis

Strengths	**Weaknesses**
• High potential value • Recovery of stomachs utilises material which is normally discarded at sea • Head and gut recovery offers additional income for the catching sector • Primary recovery can easily be done by most processors • Other countries have established markets and trade links for many products	• Limited access to some raw-materials • Some fish are too small to be utilised • Freezing and transport costs to reach Eastern markets • Little is known about markets • Secondary processing can be more complex requiring higher capital investment such as dryers for head processing • Not suitable for shellfish • Limited commercial experience UK
Opportunities	**Threats**
• Exploitation of existing and emerging markets • Opportunities to develop new niche products • Establishment of regional collection and transport systems • Currently 3 proposed head drying initiatives looking to establish in the UK provides opportunities for supply	• Current trends for using headed and gutted fish reduces the amount of raw material available • Businesses jumping on the band wagon could lead to over supply of some markets • High production and distribution costs will impact on viability

Conclusion

The utilisation of these edible by-products has potential. Opportunities include the establishment of either individual or a regional collection and transport system and primary and secondary processing facilities.

Each new venture would have to be carefully assessed on its own merits using a detailed cost-benefit analysis. But relatively unknown markets already exist, along with the potential for developing new niche markets. A key part of the study would be to focus on identifying these markets, sourcing the raw material which is currently disposed of at sea, getting it to the processing plant in a suitable condition and studying the production of these 'specialist' products to maximise profits.

The timescale for setting up a primary product recovery operation should be relatively short, less than one year. Secondary production could be longer depending on the nature of the business proposed.

1.2 Mince

Mince is produced by recovering flesh from whole fish or the frames which are left over after filleting. There are several grades of mince, with the highest grade made from fresh, carefully prepared raw material, is light in colour with few dark flakes or pieces of belly cavity. The lowest grade mince is produced by de-boning fish frames, resulting in a dark coloured mince.

Mince can be made from a wide range of different types of raw-material, ranging from white fish, oily fish or crustacean waste. Mechanical separation is the preferred technique for flesh removal. Chemical separation gives a higher yield but results an inferior quality mince. In large-scale production, the mince is typically frozen in plate freezers to make commercial blocks. On a smaller scale, the mince is either frozen in a blast freezer or incorporated immediately into new products.

Mince has many uses. The highest grade of mince is used for human consumption to make reformed products, whilst lower grades are typically used for pet food manufacture. In smaller businesses the mince may be frozen, formed directly into new products or sold fresh or frozen as pet food.

There are currently no large scale commercial fish block manufacturers producing commercial blocks for human consumption in the UK. However, there are businesses either producing mince for pet food manufacturers or processing the mince for incorporation into fishcakes etc.

Economics and scale
Small scale mince production can be relatively inexpensive. Basic de-boning equipment with a capacity of 0.5t/hr costs from around £15,000 and can easily be incorporated into a business's existing infrastructure. Freezing equipment depends on capacity from about £12k (0.5t/h). A simplified cost-benefit analysis was detailed in a recent report (Ref 7). Other factors to consider include hygiene, labour packaging and transport costs.

The price paid for the mince is dependant on the grade. A scheme to produce mince in N.E Scotland failed because the price of the end product exceeded the marketable value of the grade of mince produced.

SWOT analysis

Strengths	Weaknesses
• Flexibility in the type and scale of the process • Utilisation of a good range of raw material • Wide range of products can be produced • Mince can be frozen for use by a third party	• Large-scale producers face high capital and operational costs. • Legislative requirements set very high standards of hygiene and operation • The markets for all grades of mince need

or used directly to make additional products in-house. • Can be established within existing premises	identification
Opportunities	**Threats**
Development of new markets such as high quality pet-food, food ingredients or new food products. Markets exist for the leftover bone such as gelatine production, charcoal and land remediation. Opportunity exists since to set up an infrastructure to supply existing mince manufacturers with high quality raw-material.	• Supplies of commercial blocks from China are set to dominate the world markets for the foreseeable future. • Obtaining a source of UK high quality raw material may be difficult. Guidance on chilling and storage to maximise the freshness of the raw-material is required • Without the development of new markets, an excess of mince blocks may quickly flood the market place, driving prices down.

Conclusions
Small and medium scale mince production looks practicable for reducing waste at source. A range of options exist including direct production of mince or mince products and supplying an existing mince producer. Opportunities may also exist to develop a collection and transport infrastructure which will help to supply mince producers with top quality raw material that has been handled correctly. Each new venture would have to be carefully assessed on its own merits through a cost-benefit analysis. Operations would be most likely to succeed in an area with a concentration of processors but situated away from a fishmeal plant, such as the South-West of England. A key part of the study should focus on the identification of existing markets and the development of new markets for a range of different types of product.

The timescale for setting up a mince production operation should be relatively short, less than one year depending on the nature of the business proposed.

1.3 Roe and Milt

Fish roe is derived from the eggs carried by female fish during the breeding season. Milt (fish sperm) can also be eaten.

Some of the most popular roe products come from cod, herring, capelin, lumpfish and salmon. In Japan there is also a market for crab and sea urchin roe. Harvesting herring roe on kelp has become a significant industry.

For the European market, herring roe is commonly machine processed to give a product which consists of separate non-sticky eggs. However, for the Japanese market the whole organ or roe sack may be removed by hand. Although labour intensive, in this form it is considered a delicacy and commands a much higher price. Interest is growing concerning the use of roe as a nutritional feed for fry.

Some of the larger UK pelagic processors are currently producing both mechanically and manually extracted roe products. No UK producers of roe products from demersal species or shellfish are known.

Economics and scale
Although reduced over the past few decades the Japanese market for roe, is currently estimated at £500 M P/A. The total value of herring and cod roe imported by Japan in 2001

was estimated at £17m and £350m respectively. The average value of frozen roe and herring roe on kelp is £3.50/kg and £11.00/kg respectively. Currently the value for salted herring roe at Osaka Wholesale fish markets stand at between £20 to £50 per kg depending on size and quality.

Mechanised roe recovery requires a substantial equipment investment in excess of £150,000. Manual extraction can incur high labour costs.

SWOT analysis

Strengths	**Weaknesses**
• For demersal fish, roe/milt recovery would maximise a resource that is normally discarded at sea • Potentially large, high-value markets already exist for some products • Whole roe removal is a relatively simple operation	• Limited access to demersal raw-material as gut material currently disposed of at sea • Seasonal production • Environmental and stock issues of roe harvesting • Mechanical separation of pelagic roe requires a substantial investment • Freezing and transport costs to reach main markets • Little is known about the existing markets
Opportunities	**Threats**
• Exploitation of existing large and emerging markets (Far East) to meet current demand • Opportunities to develop new niche products • Development of collection and transport links to obtain roe and other usable by products currently discarded at sea • May provide an alternative income for the catching sector	

Conclusion
Roe recovery is a potentially lucrative utilisation route for the catching and shore based processing sectors. Opportunities include the establishment of an onboard collection and transport system for demersal roe; primary processing of material and carrying out secondary processing operations.

Each new venture would have to be carefully assessed on its own merits using a detailed cost-benefit analysis. A key part of the study would be to focus on identifying the requirements of existing large markets, sourcing the raw material which is currently disposed of at sea and studying the production of these 'specialist' products to develop secondary processing operations to maximise profits.

The timescale for setting up a primary product recovery operation should be relatively short, less than one year. Secondary product production could be substantially longer than one year depending on the nature of the business proposed

1.4 Soups, Stocks and Sauces

In countries such as France, fish and particularly shellfish are used in the production of soups, stocks and sauces for retail sale. Fermented fish sauces have been produced since ancient times and are still extremely popular in many Asian countries where they form a staple part of the diet.

The process is relatively simple, involving boiling the seafood with a range of other ingredients and spices, followed by packaging and storage methods applicable to the end user. Fermentation is used to develop a more intense sauce but is a more involved process. Further information on fermentation is included in Section 2.1.2 on silage and in Section 2.2.4 on fish protein hydrolysate.

In the UK there is a demand from restaurants and 'time poor' home chefs for good quality fish and shellfish stock. A few UK businesses exist in both commercial production (Joubere) and supply of raw material to both commercial and domestic producers. Some companies are already making specialist stocks from crab for sale to restaurants.

Economics and scale

The actual costs of establishing a stock, soup or sauce production facility are unknown although are though to be medium to high cost depending on the extent of the facility and the complexity of the process. Costs could be lower if these processes are developed within a facility that already has some of the infrastructure available.

SWOT analysis

Strengths	**Weaknesses**
• Can utilise many types of fish and shellfish • Significant export market • Size of business can be scaled • Could be part of an existing processing operation	• Some raw material is disposed of at sea • Limited UK markets • Strict hygiene legislation for cooked products • Generation of waste
Opportunities	**Threats**
• Production of stock or supply raw material for manufacturers • Establishment of a regional collection and transport system • New ranges of stocks and soups and development of new niche products • Businesses producing cooked shellfish already produce a basic stock which is discarded as part of the normal process • Could be integrated into a facility producing a range of products	• Competition could lead to over supply • Accessing high quality raw material • Maintenance of high freshness quality standards • Traceability issues associated with a regional facility • Consumer perception

Conclusion

Stock, sauce or soup production appears to be a potentially viable utilisation route. There are a range of potential opportunities including collecting material which is normally discarded at sea, supplying raw material to both commercial and domestic producers and in the production of basic or complex products. Each new venture would have to be carefully assessed on its own merits using a detailed cost-benefit analysis. A key part of this study should focus on identifying new and existing markets and sourcing raw material which is currently none or under utilised disposed. Studying the production methods of higher value products which appeal to Eastern markets would also allow UK businesses to maximise profits. The timescale for setting up this type of facility is considered as 1-2 years depending on the nature of the business proposed.

2. Options for the recovery and recycling of seafood waste

2.1 Recycling opportunities for all types of seafood waste

2.1.1 Fishmeal and Oil

Fishmeal and oil production is allowed as a processing method for Category 3 by-products. A fishmeal facility requires inspection and approval from the State Veterinary Service. They also require licensing and approval under environmental protection legislation.

UK fishmeal producers accept finfish waste, including farmed fish processing waste, and some shellfish material. Shell is not included in the fishmeal process. Shellfish wastes containing high levels of grit, such as scallop, are also unacceptable.

The first stages of fishmeal production are mincing the fish (if required), cooking and pressing which yields two products; liquid presswater and pressed solid presscake. The raw material is generally heated to between 80-90^{o}C for 15-20 minutes. Presswater is desludged to remove any solid particles, which are then added to the presscake. The desludged presswater is then passed through a centrifuge to separate oil from water. The crude fish oil is further processed or sold whilst the stickwater is fed back into the process. The presscake, along with the material from the presswater, is dried and ground to produce fishmeal.

Although there are variations in production methods, such as low temperature drying, the fundamental principles remain the same.

There are also crude forms of fishmeal production including heat treating the seafood to specific temperatures to cook/dry the material in one step. However this produces a lower value material.

Economics and scale

The price paid for seafood waste is linked to world fishmeal prices. Processors receive a variable rate for material supplied to the fishmeal plant, depending on freshness quality, oil and dry matter content, and whether it is whole fish or processing waste. Deductions are made if freshness quality and free water content exceed the set limits and whether any foreign objects are present.

Currently demersal fish processing waste can generate income of up to £40/tonne but £10-£30 is more common. Pelagic fish may generate an income of up to £70/t with about £30/t more common.

For processors located away from the two main fishmeal centres (Humber region and NE Scotland), transport costs are deducted from the raw material value. Therefore in NW England, processors currently receive about £18/t, whilst in NE England processors receive £26/t. The situation is very different in SW England where the processors pay a haulier up to £30/t to collect and aggregate batches of seafood waste for transport to the Grimsby fishmeal plant.

The feasibility of establishing a fishmeal plant is very dependent on raw material availability. A large capacity fishmeal plant processing approximately 50-100 tonnes of raw material per day costs upwards of £8.5 million excluding ancillary services. Smaller capacity plants of 1-5 tonnes per hour cost between £100,000 and £700,000. Additional components and environmental controls would also have to be included. Operating costs are very high as it is an energy intensive process. Fishmeal from small-scale plants can vary in quality and composition making it difficult to achieve market prices. There is currently only one small scale fishmeal plant in the UK which only operates over part of the year due to the high operating costs. Fishmeal is generally only considered commercially viable on a large scale.

SWOT analysis

Strengths	Weaknesses
• Established infrastructure in the UK to collect material • Proven technology • Provides revenue for some parts of the finfish and shellfish industry in the main processing regions • Provides revenue and/or covers the cost of transporting material from regions located some distance from the fishmeal plants • Established markets for fishmeal • Can take all finfish material from the wild caught sector • Worldwide fixed price and demand for fishmeal	• There are only two fishmeal plants in mainland UK and one in Shetland which impacts on national availability and incurs transport costs • Cannot accept most forms of shellfish waste • Large scale facility required to make cost effective • Small-scale plants are expensive and suffer variable quality outputs and fluctuating demand
Opportunities	**Threats**
• The onshore sector is largely dependant on this option • Increasing world-wide demand for aquaculture feed	• Animal feeding controls becoming tighter • Competition from other protein sources • UK fishmeal is made largely from processing waste and must be relevant quality to compete with other meals comprising whole fish • Processors unwilling to maintain best quality raw material

Conclusion

It is vital that the seafood industry continues to supply the remaining UK fishmeal plants to ensure that they remain operational. At the moment it is the most sensible option available for industry given that other routes are costly. In general there are very few industries that receive money for their waste and so the seafood industry should continue to support this valuable route

There appears to be limited potential for developing small-scale fishmeal plants in the UK due to the high costs, variable raw material, variation in end-product quality and composition and the requirements for environmental controls. The quantity of seafood waste produced in regions located away from the fishmeal plants do not seem enough to make establishing a small-scale plant viable.

Recent collaborative initiatives have been developed to establish regional collection and transport links. This allows industry to collect material together to aggregate a batch that is economical to transport to one of the two fishmeal sites. It is recommended that these regional initiatives continue, with industry putting effort into improving the handling and refrigerated storage of the material. This can easily be established within a one year timescale.

2.1.2 Ensiling

Ensiling is a permitted option for both Category 2 and 3 seafood. The by-products must be reduced to 30 or 50mm (depending on the level of subsequent heat treatment), mixed with formic acid to reduce the pH to 4 or less and then stored for 24 hours pending further treatment. At this stage, ensiling is only classed as a storage or intermediate process. Before the ensiled material can be used for other purposes, it must be heat treated to a core temperature of 70 or 90^{o}C (depending on the initial size of material used) for at least 60 minutes.

Ensiling units can vary from 250-2000 litres. Generally fish is minced or chopped before it is put into a mixing tank where it is mixed with formic acid at 3.5% to acidify it. The pH is maintained to less than 4 to prevent spoilage. Enzymes break the material down into a thick, viscous material which can be held in bulk storage. In warmer countries, ensiling is also carried out by adding a carbohydrate source and maintaining temperature to about 30^{o}C.

Currently ensiling is used by the finfish aquaculture industry to treat mortality waste from fish farms. Generally when the farm has a large quantity of ensiled material available, one of four companies in the UK will collect. Two of these companies export to Norway whilst one facility in Scotland collects only Category 3 material which is reprocessed into a number of different products. Another Scottish company collects ensiled material, which is sent to England for incineration. Some fish farms are known to be landfilling ensiled material due to the higher costs of collection by these other routes.

Economics and scale

Scottish fish farmers face costs of about £30-£40 per tonne for collection of ensiled Category 2 material.

To establish a facility the costs are variable depending upon the size of the facility required and where the ensiled material is despatched. The following table summarises the direct costs associated with a 2000 litre capacity tank, for the basic ensiling process. (Ref 8)

	2000 litre capacity plant
Capital cost	£8,000-£20,000
Storage tanks and ancillary equipment	£11,000
Operating cost (includes acid, labour etc)	£4,000-£7,000 pa
Total costs (based on £8,000 capital costs) - if land injected - if exported - if collected free	 £55/t £89/t £31/t

If the material is to be used for other purposes, which necessitates heat treatment, further significant costs would be incurred although exact figures are unknown. These could be offset to some extent by the sale of the processed material if this ever becomes available although this appears unlikely.

Ensiling could be carried out from either small scale, in-house level up to a large scale plant taking all material from a region. Establishment costs are relatively low for the basic ensiling process and so this could be an adaptable storage/intermediate process. However, if the material is to be used for other purposes which necessitate heat treatment, the facility would have to be large enough to justify the required investment. The options available for utilising ensiled material are currently low in the UK and would require significant invest to address.

SWOT analysis

Strengths	**Weaknesses**
• Can treat all forms of finfish waste • Simple, low technology • Low running costs	• Requires additional heat treatment for further use which is largely absent in the UK

• Low environmental impact • Variety of sizes available to suit a range of different throughputs • Relatively quick treatment process	• Material has to be disposed of or exported if it is not further heat treated • Variable quality and composition can affect value of the ensiled product • Requires large volumes of acid • Questionable whether can treat all shellfish waste • Not currently used by the wild caught sector • Irregular collections necessitate bulk on-site storage facilities • Processing/collection infrastructure is centred in Scotland so may be limited on a national basis due to high transport costs • Would need several large units to treat large quantities of material • The need for heat treatment considerable increases the costs of this option • Concerns over Category 2 by-products and inactivation of pathogens
Opportunities	**Threats**
• There are four companies in Scotland who collect ensiled seafood waste • Plans for developing further treatment facilities in Scotland (although already delayed) • Formation of bacteriocins may have potential for replacing antibiotic growth promoters in young pigs • Use as a storage or intermediate process for regional developments • Potential for dewatering to reduce transport costs • Ongoing research to identify extent of pathogen inactivation • Inclusion of oily fish makes further treatment or separation increasingly viable so is suited for pelagic species, salmon and trout	• Reliance on export markets which have no long term contracts • Future animal feed uncertainties and restrictions

Conclusion

Ensiling is a potentially feasible option for processors in some parts of the country where other options are limited. This is the case in Scotland where facilities currently exist to collect and export the ensiled material from salmon farms, although the long-term viability of these routes is uncertain. Ensiling is a useful storage method but there are major concerns over the use and limited options for using the finished product.

Attempts to develop ensiling facilities over the past 20 years in the wild caught sector have been unsuccessful. High transport costs, variability of raw material and end markets have contributed. Although there is scope for animal feeding, the additional heating costs and ancillary equipment required to meet ABPR may preclude this as a viable option.

A recent review in SW England (Ref 7) referred to the development of a regional ensiling facility as an option for the wild caught sector. It was felt that viscera would be required to ensure the process worked. Unfortunately the majority of viscera is discarded from UK fishing vessels and it is difficult to see how this could be altered without some financial incentive for the fishermen. This would impact on the costs.

Ensiling could be established within 1 year as a regional storage method. However this would not be sensible unless there is significant development in infrastructure and final uses, which would take 2-3 years to complete.

2.1.3 Rendering

For seafood by-products, the main form of rendering is fishmeal production however rendering animal by-products and food waste is available as a separate waste treatment process. The rendering industry was established to treat mostly meat based by-products.

Rendering is a permitted option under the ABPR for all categories of animal by-product. There are currently 6 processing (rendering) methods for treating animal by-products, which specify criteria for treating the animal by-products including initial particle size, time and temperature. There is provision to adopt other methods for treating animal by-products, which stipulate the finished product must be sampled on a daily basis over a period of one month and found to be free of *Clostridium perfringens*, *Salmonella* and *Enterobacteriaceae*.

A rendering facility must be licensed in accordance with ABPR which requires inspection and approval from the State Veterinary Service. Rendering sites also require licensing and approval under environmental protection legislation.

The rendering process involves crushing and grinding of animal by-products followed by heat-treatment to reduce the moisture content and kill micro-organisms. The fat is separated from the protein. The fat is then used in products such as animal feeds or processed into chemical derivatives which are used in a wide range of industries. The protein is ground into a powder, such as meat and bone meal, and used in various products.

Economics and scale

If a company wishes to send material to an existing rendering company, the costs are in excess of £45/t plus transport and disposal of the finished material (if no uses exist). Each rendering company will set its own price. The indications are that seafood processors would pay more because of the limited value of the products produced. Some companies are currently paying rendering costs in excess of £100/t.

The majority of renderers are large scale, handling material from a number of different sources. Facility establishment and operating costs are high, necessitating a large throughput of material to be treated. Discussions with rendering companies have cited costs of complying with legislation particularly environmental controls as significant which would be difficult to justify in a small-scale facility. As such, this is considered a high cost option if a new site was to be established.

SWOT analysis

Strengths	**Weaknesses**
• UK infrastructure already exists • Rendered by-products can be used for other purposes • Accepts all categories of waste (subject to licensing) • Established transport routes • Proven technology and process • Accepts most raw materials including	• High capital costs to develop a facility • UK infrastructure developed for animals other than seafood • Some products (shell) require additional treatment stages or disposal • Facilities are not always available in seafood production areas • High processing costs

packaged products	• Not all renderers accept seafood waste
Opportunities	**Threats**
• Range of uses for rendered by-products (fertiliser, biogas etc)	• Competition form other waste management options • Restrictions on animal feeding may limit some final uses

Conclusion

Rendering in the conventional sense is not considered a viable treatment process for industry to establish. Although the use of the existing rendering infrastructure is potentially feasible this is not without problems. The United Kingdom Renderers Association has suggested that their members can only take 5% of their throughput from seafood as it can taint their finished products (tallow, fats etc). Some members of the seafood industry report that renderers are not willing to take seafood waste. Renderers are not always based in regions convenient to the seafood industry which results in high transport costs to suitable facilities.

2.1.4 Composting

Composting of seafood waste is permitted at premises approved by the State Veterinary Service providing it is carried out in an enclosed system, maintains a temperature of 70°C for 1 hour with a maximum particle size of 12 mm across one dimension and meeting the bacteriological standards 0 g *Salmonella* in 25 g and a maximum of 300 cfu/g *Enterobacteriaceae* according to the EU process requirements. Other controls such as obtaining planning permission from the local council and a waste management license from the regulator (Environment Agency in England and Wales, Scottish Environmental Protection Agency in Scotland and the Environment and Heritage Service in Northern Ireland) are required.

Composting is the controlled decomposition of biodegradable materials under managed conditions that are predominately aerobic. It allows the development of high temperatures as a result of biological action to produce compost that is sanitary. It takes a further 6-8 weeks to produce stable compost, or even up to 3 months if the material is to be bagged. Depending on the quantity of waste and the system used, the waste could be sanitized and stabilised in the same vessel (10 weeks or so) or alternatively the waste could remain in an enclosed system for 7 days where it will be actively managed to control process parameters and emissions, after which the material is sufficiently sanitised to be composted in an open-air windrow to complete the 6-8 week period.

There are numerous types of in-vessel technologies available to suit a wide range of applications. Trials on composting seafood have been carried by both Seafish and Bord Iascaigh Mhara (Irish Sea Fisheries Board).

Economics and scale

The capital cost of setting up a facility will vary greatly. The two largest expenses will be the in-vessel system and the concrete pad on which to build the facility. A concrete pad costs in the region of £35 per square metre, so it would cost £350,000 per hectare or £140,000 per acre. As a general rule of thumb approximately 1 square metre is required for every tonne of compost (The Composting Association 2001), so a medium size facility processing 20,000 tonnes would cost £700,000. If an existing concrete site could be used then significant saving could be made. A site with the same capacity processing all the material through an in-vessel system would need to invest up to £2 million in in-vessel technology and would have an operational cost of approximately £0.5 million/year

Composting systems tend to be modular in design and can therefore cover all scales of production. In reality, however, legislation and competition within the industry or with other treatment options will drive economies of scale. Principally, the investment that is required should determine the quantity. At present there are small-scale, localised facilities such as on-farm options, which can be economically viable, but the cost per tonne reduces as the scale is increased.

SWOT analysis

Strengths	Weaknesses
• Takes all types of seafood waste • Technology is widely accepted • Aerobic process reduces odours generated • Produces a sanitised product that can be applied to land • Potential to generate income from products • Economically viable compared to many treatment options • Versatile range of modular units so the capacity can be scaled up to meet demand • Animal by-product compliance can be achieved • Reduces emissions to land • Volume reduction achieved • Seafood compost proven in plant growing trials	• Large site required for full scale commercial facility • Products must compete with other biodegradable wastes outlets • Very low C:N ratio so will need to be mixed with a high proportion of other wastes • High nitrogen content of product means a greater area of land required for spreading particularly in Nitrate Vulnerable Zones (NVZ)'s but fish compost is more effective in Nitrogen poor areas. • Protracted timescales to start facilities due to planning and licensing procedures • Process time fairly long compared to other treatment methods • End product has a low bulk density increasing transport costs • Odorous feedstock (can be mitigated by enclosed facilities and use of odour filters) • Possible vector attraction e.g. flies
Opportunities	**Threats**
• Generate gate fees from other waste sources • Potential solution to the disposal of seafood wastes • At present an open market for seafood waste composting	• Increasing legislative demands on the industry • Some composting sites have been closed due to odours • Increasing number of competitors

Conclusion

The composting of seafood waste is a commercial reality in the United States and Canada. Although there are no facilities in the UK, demonstration projects have proven its technical feasibility. The UK currently has at least 14 in-vessel sites that are approved to treat Category 3 animal by-products. The seafood industry could therefore build composting plants to provide a solution to their waste in the short-medium term. Composting infrastructure is being built by the waste management industry, itself, but may take some time to be widely available

There are several potential threats but these may be mitigated by location of the facility, design and process management. Obtaining planning permission has been the main obstacle to setting up any waste management facility. Even if the local authority is positive, the local community may have objections. As the generation of odours is pre-conceived, measures to mitigate these should be considered in the planning stage. It is reasonable to suggest that obtaining the necessary permission, procurement and construction will take 2-3 years.

2.1.5 Accelerated (Thermophilic) Aerobic Digestion

Aerobic digestion of food waste is regulated under the same regime as composting and anaerobic digestion with a time temperature requirement for 70°C for 1 hour. Planning permission and environmental protection controls are also required.

Aerobic bacterial digestion is the process of bacteria consuming organic matter in the presence of air. The organic waste is metabolised down to water and carbon dioxide, the final metabolic waste products, providing the bacteria with energy for growth and reproduction. For liquid phase aerobic treatment the waste material is macerated and mixed with water. The liquid containing macerated waste is transferred to reactor vessels fitted with oxygen distributors and stirring devices. Typically, 3 vessels in series are used. In the vessel thermophilic bacteria generate heat up to 80°C. Between 2 to 20 days hydraulic retention time is estimated for treatment. The fastest rate of breakdown occurs at the start of the process so retention times of 2-6 days can achieve the desired reduction in activity.

There are currently demonstration scale and commercial scale facilities available in the UK. Trials have been carried out on seafood which have shown positive results.

Economics and scale

A one tonne/hour demonstrator unit is currently available from one supplier. Although small aerobic systems can be constructed with reactor capacities as low as 4 m^3. As the systems are modular, there are economies of scale with larger plant.

SWOT analysis

Strengths	**Weaknesses**
• Takes all types of seafood waste • Can potentially treat to ABPR standards to enable land spreading • The treatment reduces offensiveness of the product when recycled to land or used in dried products. • Modular design • Small footprint • Self heating • Nitrification is inhibited at high temperature, which also provides an opportunity to remove ammonia. • Fast start up • Ability to treat a single waste stream • Low labour • Batch processing • Fast processing time	• Some systems need to add liquid such as water • No reduction in the volume of the wastes treated in the aerobic process • A recycling route to land is needed or markets for products have to be accessed. • Separation and drying adds considerable costs • Markets for the organic fertiliser produced are competitive. • Shell material may accumulate in the base of the tanks but could be removed as settled sludge in sequencing operations • High solid (6-12% DM) wastes complicate mixing.
Opportunities	**Threats**
• Organic fertiliser sales as liquid and solid.	

Conclusion

The technology is well understood and trial units are available to test different waste combinations, which reduce the risk of installing an unsuitable treatment system. The high degree of automation and the ability to treat a single waste stream are advantages of the system. The modular construction of some systems means that they can be considered for stand alone application at individual, large-scale processors.

Although it is technically possible to treat seafood waste by aerobic digestion, a very thorough economic feasibility study would be necessary before proceeding down this route. This technology may be prohibitive unless carried out on a regional scale with a reliable throughput of waste. Success would probably be dependent on gate fees and sales revenue and the venture would need to be operated as a proper waste treatment business.

2.1.6 Mechanical and Biological Treatment (MBT)

The objective of MBT is to reduce the biodegradability of the waste stream. MBT refers to a variety of processes that treat waste using physical and biological processes. There are usually several different outputs from the process, some of which are biodegradable and may go to landfill for disposal. There are many possible configurations of MBT however the main plants are based either on ‘splitting’ or ‘stabilisation’. In ‘splitting’ waste is usually separated, with a proportion treated biologically. In ‘stabilisation’ the entire waste is subjected to biological treatment with subsequent splitting of the mass of stabilised material for recycling, refuse derived fuel (RDF) and landfilling.

As this option includes a range of different possible technologies, it requires further evaluation to establish options suitable for the seafood industry.

Economics and scale

MBT plant involves high capital investment (£8 million) and is primarily developed for municipal waste. Transport cost (for 100 miles) to the few centralised sites that exist will be in excess of £40/tonne.

Large throughput is required to be cost effective for municipal wastes. Those plants proposed and operated have capacities of 10,000-40,000 tonnes per year. The mechanical pre-treatment prior to composting could be simpler though more specialised for the seafood industry so small to medium scale mechanical separation treatment on site is needed.

SWOT analysis

Strengths	**Weaknesses**
• The non-biodegradable components are removed for other applications and the stabilised materials can then go to landfill without compromising diversion targets or they can be recycled. • Lower transport costs due to fewer collections • There are a number of options available	• For most shellfish the organic material is bound strongly to the shell. • The different components still need to comply with the ABPR. Landfilling of the wastes will not be allowed to continue unless the treatment has time and temperature regimes that meet ABPR requirements. • Generally large-scale facilities as they are designed for municipal solid waste streams
Opportunities	**Threats**
Range of possible processes available	

Conclusion

Any system that removes intestines from shell and then biologically treats the shell to stabilise the organic material on the shell can be classed as MBT. Provided that the treatment also meets time and temperature regimes then classic MBT to landfill is an option. The stabilised treated materials are likely to have benefits when recycled for land drainage, fertilisation or other uses that will have lower costs than landfill.

It is recommended that mechanical or biological treatment for the shellfish waste is considered as a pre-treatment to produce clean shell that can go for the ABPR specified land application technical routes or for other uses. For example, removal of shell from intestines that go to anaerobic digestion or size reduction of shell before anaerobic digestion or composting are examples of mechanical treatment that can be recommended for seafood waste.

2.1.7 Autoclaving

Autoclaving involves heat-treating waste. Heat treatment is a permitted option under the ABPR for all categories of animal by-product. There are currently 6 processing (heat treatment) methods for treating animal by-products, which specify criteria for treating the animal by-products including initial particle size, time and temperature. There is provision to adopt other methods for treating animal by-products, which stipulates that the finished product must be sampled on a daily basis over a period of one month and found to be free of *Clostridium perfringens, Salmonella* and *Enterobacteriaceae.*

Autoclaving operates as a batch operation. After loading with waste the autoclave drum is sealed and rotation re-started. Saturated steam in excess of 140°C is injected into the vessel. The pressure in the vessel is maintained at 5 bar for a period of up to 45 minutes to allow the process to fully "cook" the waste. The autoclave process gives a very high pathogen and virus kill. A combination of the steam pressure and mechanical action of rotation results in the organic fraction of the waste being broken down and the inorganic fraction being sterilised and steam cleaned.

Economics and scale

Capital cost can range from £600,000 to £12,000,000 for 500 to 500,000 tonnes per annum (Ref 11) throughput. Operating costs are not available but considered high because of the energy consumption.

Small-scale operations appear feasible. Proven commercial systems are offered for municipal solid waste (MSW). However, simple batch systems for seafood wastes would not be difficult to incorporate into sites with existing steam plant.

SWOT analysis

Strengths	Weaknesses
• Possibilities of treatment at lower temperatures for longer periods. • Small on site processing is possible so accessible to individual businesses. • The resultant material will have soil pH raising properties (liming effect) • Full sanitisation of the waste • Autoclaving technology is proven on non-MSW applications	• Energy cost • Odour from recycling of the material to land • No reduction in mass of the material so relatively high recycling & transport costs • Product must be cooled before recycling • Perceived as new technology • Difficulties in adequately containing the steam and potential odour release when opening and subsequently cooling autoclaved waste • Need to treat effluent stream from steam condensate
Opportunities	**Threats**
• Steam generating plant on site can reduce investment costs. • Residual heat in the product after process cooking can reduce treatment costs • Heat can be recovered	• Investment in facilities without secure contracts would be vulnerable to undercutting by other facility providers. • Hygiene and operating approvals and building requirements will add significantly to the cost

• Shell or fish frame cleaning would produce a saleable product	of low capacity installations. • The process does not substantially reduce the biodegradable content of waste. • Public perception

Conclusion

The treatment makes the wastes acceptable to recycling options such as land spreading or use for other permitted options under ABPR. Category 3 seafood wastes can be treated in simple heat treatment processes. The small footprint of the process may make this a feasible option as a route to lower cost recycling using the basic system components of the treatment vessel and bio-security measures without the large pre-treatment and separation components of systems designed for MSW.

The large-scale processes designed for MSW are not likely to be suitable for direct investment by the seafood industry. The technology is relatively new to the UK and it is still early days for uptake with only one MSW Kidderminster site approved to date. The large facilities are likely to be few and far between so contract treatment does not represent a viable option for the wider industry in the short-term.

2.1.8 Alkaline Hydrolysis

Alkaline hydrolysis is currently a permitted process for treating all categories of animal by-product. For seafood waste, alkaline hydrolysis requires operating at 150^{o}C for 1 hour, using an alkaline solution of sodium hydroxide, potassium hydroxide or a combination of both. Potassium hydroxide is considered the preferred alkali. The residue from the process could potentially be used as a soil improver.

The process is carried out in a digester, which consists of an insulated, steam jacketed, stainless steel vessel with a lid. A basket is used inside the vessel for bone remnants. The capacity of one manufacturer's digester varies from 14kg to 3.6 tonnes.

During operation, a measured amount of alkali, proportional to the amount of tissue in the basket, is automatically added to the material in the digester. Water is added to cover the waste and the vessel is sealed. Digestion time is set according to the type and category of material in the digester.

The material dissolves and is hydrolysed into smaller molecules, ultimately producing a sterile, alkaline material.

Economics and scale

Costs are provided from the manufacturers Waste Reduction Europe. These costs do not take into account site establishment costs and use/disposal of the treated material.

Costs associated with alkaline hydrolysis

	127 kg capacity	680 kg capacity
Annual capacity (based on 8 cycles every 24 hours, 365 days/yr, digestion at 150^{o}C for 1 hour)	370 tonnes	1985 tonnes
Capital cost of digester	£157,000	£272,580
Operating cost (includes sodium hydroxide, steam, electricity)	£26/t	£26/t
Overall cost per tonne of raw material	£68.31	£39.72

Considering these figures, alkaline hydrolysis is considered as a medium to high cost treatment.

Alkaline hydrolysis appears best suited for a large, regional scale facility as the figures indicate that it requires continuous operation to be cost-effective. It is questionable whether it is suitable for a regional solution as the largest capacity digester is 3.6 tonnes. A regional facility would therefore need to have more than one digester to process the amount of material produced and this would vastly increase the costs.

Although there are small-scale units available, the establishment and operational costs are considered too high to make this feasible

SWOT analysis

Strengths	**Weaknesses**
• High level of waste volume reduction • Sterile residues • 'Clean' technology • Approved process • Relatively small footprint • Small-large scale facility • Relatively quick treatment time for fish (one hour)	• No private or commercial facility available in the UK • Expensive capital and running costs • Requires water/dilution prior to treatment • Effluent discharge costs • Storage of sodium hydroxide
Opportunities	**Threats**
• Suitable for all categories of waste	• Unclear whether shell is reduced in volume • Uncertainties over legalities of applying treated material to land • Competition from other waste treatment methods • Questionable benefits compared to other options such as rendering or ensiling

Conclusion
It is difficult to see how this would be a sensible option for the seafood industry to develop in-house. Other methods are available which achieve similar results at lower cost.

It is possible that alkaline hydrolysis could be developed on a regional basis but this would have to be considered against the range of other options available. Alkaline hydrolysis is probably more appropriate for treating Category 1-2 material which justifies this higher level of treatment.

2.1.9 Direct animal feed including bait

There is a range of possible options for direct animal feeding. Raw, UK sourced, Category 3 seafood by-products can be directly used for bait as lures on hooks or in pots, with no requirements for pre-treatment. Direct feeding to zoo animals is also permitted to but animal feed controls come into effect. The use of waste for maggot farming is also permitted if the maggots are used for fishing.

There are several routes for utilising waste for direct animal feeding. Maggot farms require a supply of material for the production of maggots for sport fishing. Likewise material is also used by crab and whelk fishermen to bait hooks or pots, in the farming of worms for sea fishing and for direct incorporation into long line baits. For the purposes of this study the focus is largely on the direct use for bait

Economics and scale

Some processors receive about £20 to £30 per tonne of material whilst others will give waste away to local fishermen, particularly when supply exceeds demand. This solution is very locally based.

SWOT analysis

Strengths	**Weaknesses**
• Acceptance of low quality material for crab and whelk bait. • Can use all types of waste • Permitted technical disposal route	• Seasonal demand • Relatively small volumes of fish waste required • Seasonal over supply
Opportunities	**Threats**
• Use clean bones from maggot or worm farming for land reclamation • Potential for formulated long line baits	• Businesses jumping on the band wagon leads to over supply

Conclusion

Bait is a viable utilisation route for waste at a localised level. It is already widely used by fishermen who value its availability. Other options for establishing a maggot or marine worm farm or supplying raw material for direct incorporation into bait exist but these are more complex and expensive. Each new venture would have to be carefully assessed on its own merits using a detailed cost-benefit analysis. Particular attention should be given to odour control and planning permission. The opportunity to sell the resultant waste i.e. clean bones for other utilisation routes should also be included.

The timescale for developing bait options is less than one year but it is not a route that could handle large amounts of processing waste arising from the industry although it should be encouraged due to its simplicity. More complex facilities could be substantially longer, at 2-3 years depending on the nature of the business proposed.

2.1.10 Fertilisers and Soil conditioners

There are a number of fertiliser and soil conditioner products currently in existence throughout the world that are produced from seafood waste. A number of methods are employed to produce fertilisers or soil conditioners including composting, rendering, drying at high temperatures and digestion (either aerobic or anaerobic). The seafood is broken down into its liquid and solid phases, which produces a nutrient rich fertiliser. Further details of these methods can be found in other sections of this report.

Economics and scale

Although actual costs are unknown they will vary according to the scale of the plant and type of process used. Production of fertilisers is considered to be a high cost option as heat treatment or high capital costs are usually required. In recent years there have been two projects put forward for developing fertiliser products from fish, both in excess of £3 million but both have failed to materialise. Bio-systems are difficult to scale up but are in use in USA and New Zealand.

A large-scale facility would be required to produce enough material to satisfy demand.

SWOT analysis

Strengths	Weaknesses
• Utilises bulk quantities of all types of seafood waste • A range of well known and proven technologies • Proven benefits to crops and soil • Can produce high value products	• Restrictions on use in pasture land • May require an expensive conversion process • Variable composition of the finished products can restrict value and marketability
Opportunities	**Threats**
• Can be certified organic if seafood waste from the wild caught sector is used • Added value of crustacea products e.g. beneficial properties of chitin in soil	• Competition from other fertilisers • Increasing concerns on animal by-products may increase restrictions in future

Conclusion

Despite the range of possible processes available, the cost of fertiliser production and soil conditioners is high, necessitating a regional development. It would require guaranteed throughput of raw materials to make the venture sound and there would be technical hurdles to overcome to develop consistent grade products, in light of fluctuating raw material composition and availability.

A number of ventures to develop liquid fertiliser from seafood waste have been proposed in the UK in the past 5 years, but have not reached commercial reality. Reasons have been cited including siting in areas where industry is paid for their waste or that the technology required further development. These problems are not insurmountable but would take time to resolve. As such it is clear that developing a seafood based fertiliser production facility could possibly 2-3 years from start to end, even with assistance from companies abroad who are already operating such plants.

2.1.11 Pharmaceuticals, Cosmetics and Fine Chemicals

A range of medical and high value chemicals has been produced from fish and shellfish. Antifreeze proteins have been extracted from the blood of cold-water fish. These glycoproteins are known to protect mammalian cells at cryogenic temperatures, and have found uses in the cold storage of donor tissue and organs. Deoxyribonucleic acid (DNA) is commercially extracted and purified from cod, herring and salmon milt in Tromsø, Norway for pharmaceutical use. The DNA can be further processed into the drug AZT, which has been used in the treatment of HIV. Research has been carried out into glycogen poly-sugars which are contained in the stock left over from boiling scallop processing waste. The sugar has been shown to have anti cancer properties when injected into animals at a dose of 200 mg. Squalene is a naturally occurring hydrocarbon found in some plant and fish oils. It is commercially extracted from shark livers. Squalene has been used to treat diabetes, cancer and tuberculosis in Japanese hospitals. It also has anti-fungal and antioxidative properties, providing scope for other pharmaceutical and cosmetic uses. Purified squalene currently retails at about £200 per litre.

It is not realistic for individual businesses to try to emulate established pharmaceutical companies in producing these types of products. Because of the high capital investment and level of specialist expertise required for each utilisation route; the most effective solution would be to work with existing pharmaceutical companies to supply raw materials.

2.1.12 Landspreading

Landspreading is not strictly a treatment for seafood waste but is included here as it offers a range of possibilities for using treated seafood waste on land.

Although land application is permitted there are a number of legislative issues to address. The ABPR requires Category 3 animal by-products to be treated to the required standards. Permitted treatments include composting, digestion and heat treatment (rendering). Each of these treatments has specific standards for time, temperature and particle size. There are also controls on the type of land on which the treated material can be spread.

There is an exemption from treatment for mollusc and crustacean shells from which the flesh has been removed. Their use is permitted in the production of aggregates, use in gardens, the construction, maintenance or repair of footpaths, use in draining land or for ornamental uses.

Other legal controls such as waste management licensing also need to be covered.

Before treated waste can be used in landspreading, it is necessary to analyse both the waste and soil to which application is planned, to assess the likely agricultural and/or ecological benefit. It is important that a pollution risk classification of the fields intended for application is carried out according to Water Code guidelines. This identifies non-spreading areas, suitable application rates and appropriate non-spreading periods to minimise the risk of run-off to watercourses or the pollution of groundwater.

Solid wastes are normally applied to fields using rear discharge farm manure spreaders. Incorporation into the soil should be as soon as possible after application to minimise the risk of odour nuisance. Liquid wastes are normally injected to minimise the risk of odour nuisance and there are a number of systems for injecting liquid materials. Processors would have to work with local farmers or landowners, and the relevant environmental agency to develop this option further.

Economics and scale

In addition to the treatment costs to meet ABPR, typical contracts are £15/tonne to carry and land spread. Additional costs for storage when land is not available for spreading due to cropping, soil or weather conditions, may also apply. Costs are also likely to be incurred for gaining exemptions e.g. for waste and soil analysis interpretation, field pollution risk classification and map production. The farmers or landowners receiving the wastes are only likely to be willing to pay the costs of gaining exemptions if they are gaining financial remuneration for taking the wastes e.g. for hauling waste from the treatment plant and/or spreading. Land spreading is often considered a low cost option but this is often when the cost of meeting legislative requirements is overlooked.

Landspreading can be available on a small to large scale and carried out on a local or regional basis. There are no limits to the scale of operations subject to land availability within acceptable transport distances. There may be lower limits depending on the time taken to accumulate enough waste for an efficient transport and spreading operation.

SWOT analysis

Strengths	**Weaknesses**
• Very large amounts can be recycled to land • Simple process	• Land may not be available all year round • Wet periods may further restrict access

• Low cost with typical contracts of £15/tonne to remove the waste from the producer as an end of pipe operation. • All the material is recycled. • The material has a value to the farmer or landowner.	• Odours and ground or surface water pollution from storage and application are a risk if the operation is not carried out by competent and well trained personnel. • Cost of meeting legislative requirements
Opportunities	**Threats**
• Recycling outlet for products of composting, anaerobic or aerobic digestion of fish waste treated to meet ABPR standards. • Sale of material on basis of nutrient, soil conditioning and/or liming value	• Revision to the waste management regulations – agricultural and ecological benefit criteria may change and possible reduction in maximum application rate allowed. • Competition for the available land from other landspreading operations. • Cross compliance as a result of introduction of the Single Payment Scheme (SPS) under Common Agricultural Policy (CAP) reform.

Conclusion

This is a proven method of recycling and an essential disposal route for many pre-treated waste. It is a useful fallback outlet for materials unsuitable for higher value uses. It is capable of taking high volumes of material with the opportunity to recover some treatment and recycling costs if the treatment produces a consistent high quality product. Practical for use as a local solution for some types of waste, notably clean shell, but there are restrictions and this option is less cost effective if the material has to be treated prior to land application.

2.2 Recycling opportunities for finfish waste

2.2.1 Fish bones

The bones can be used in gelatine/collagen production, filtration systems or in land remediation. There are UK companies interested in obtaining supplies of fish bone. However attempts to establish supplies from UK processors have so far proved unsuccessful as the bone needs to be largely free from flesh. As such, fish bone material is imported from the USA or Norway.

There is no specified approved method for the production of clean fish bone. Under ABPR it would be classed as a technical process, requiring an approved technical plant to be established.

Fish bone would be a by-product of a flesh separation process such as mincing or hydrolysis. The bones may need to be subjected to a further treatment such as heat or enzymic treatment to reduce the organic content as low as possible. Attempts have been made to use fish frames straight from a mincing operation but the organic matter content was too high.

Economics and scale

In 2003, clean fish bone was imported for £300-£400 per tonne. There is no information available on the costs of establishing a dedicated facility, as it would have to be developed in conjunction with a flesh recovery operation. Further costs would be also incurred to reduce the organic content to less than 40%. The optimum way to achieve this is not known. As such it is considered a low-medium cost option.

To satisfy demand, a company would need to establish a ready supply of clean bone. The backbone of gutted cod constitutes 17% of the weight so. It is estimated that approximately 5 tonnes of gutted fish would be required to produce one tonne of bone. This would only be achieved in a larger scale flesh recovery operation or regional primary production facility.

SWOT analysis

Strengths	**Weaknesses**
• Utilises a waste portion of seafood which has little other value • There are a number of options for production • Financial return on the finished product • Established market for large scale use of the material	• Competition from established imports • Only suitable for finfish waste • Utilises only a small proportion of the waste • Has to be developed in conjunction with another process such as mincing or hydrolysis • Needs a large volume of raw material
Opportunities	**Threats**
• Additional revenue stream for a mincing process	• Lack of suitable raw material • Uncertainty over legalities • Potential supply could outperform demand

Conclusion
This appears to be a suitable option for industry to establish if it is carried out in conjunction with a large scale, finfish mincing operation. Technical methods for producing clean bone along with costs and markets need further investigation. Despite this it is likely that an operation could be established within a 0-1 year timescale.

2.2.2 Collagen & Gelatine

Collagen is the most common protein in the animal kingdom. It is the principal protein found in skin and bones. Collagen can be isolated from the skin, bone and fins of fish. It is extracted by dissolving the waste material in heated dilute acid or salt solution. Collagen has may uses including isinglass, which is a clarification agent for beer, nutritional supplements, electronics industry, sausage casings and in cosmetic products claiming anti-ageing properties. It is also used in gelatine production.

Fish gelatine is a clear sweet solution with the capability to form gels. It is produced by hydrolysis of collagen in a process similar to that of fish glue production but at a much lower temperature and over a shorter time to ensure the removal of impurities. Fish gelatine has been used in photographic processing, coating applications and in the chemical etching of metals. However, it has recently seen an increase in demand in food products due to the BSE situation and the need for kosher food ingredients.

Fish gelatine manufacturers exist in USA, Canada and Italy but none have been identified in the UK. Croda UK and Aquagel ™ sell products of fish origin.

Economics/cost
Although actual costs are unknown, establishing a production facility from scratch would be significant as it requires a large scale facility.

SWOT analysis

Strengths	**Weaknesses**
• BSE free. • Wide range of uses • Kosher products	• Skin and bones must be as free from protein as possible • No simple and effective cleaning method

• Requires raw material typically left over from other utilisation options and not favoured by fishmeal plants i.e. skin/bones	• Large volume of material required • Low gel strength limits uses
Opportunities	**Threats**
• Neutraceutical market in massive growth • No UK production facility so potential for new development. • Opportunity for an existing mammalian producer to include fish • Supply of raw material	• Maintaining a supply of high quality raw material may be difficult. • Competition from other countries • Competition from other users of fish waste

Conclusions

Collagen & gelatine appears to be a viable utilisation route for waste. There appears to be opportunities to work with an existing gelatine producer to establish fish based production, or supplying raw material to producers abroad. Each new venture would have to be carefully assessed on its own merits through a cost-benefit analysis

A key part of the study would be to focus on the identification of existing markets, producers and technical aspects/suitability of the raw material. Opportunities for utilising the relatively clean bone from mince producers should be identified.

The timescale for setting supplying raw material could be relatively short, less than one year. Establishment of a production plant could take longer at 2-3 years.

2.2.3 Fish Protein Concentrate

Fish protein concentrate (FPC) is a highly nutritious powdered product made from whole fish, with a protein concentration higher than that of the original fish, intended for human consumption. Although nutritious, FPC generally has poor functional properties. Depending on its quality and degree of refinement, it can be either used as a food ingredient to boost protein content or, as in some less developed countries, eaten directly as a food product in its own right. FPC can be categorised into three grades. Type A is a tasteless, odourless white powder whilst Type B retains a fishy flavour and odour. Type C is essentially hygienically produced fishmeal.

In addition to regulatory and acceptability issues, FPC is only normally made from whole fish and hence is not considered a viable disposal route.

2.2.4 Fish Protein Hydrolysate

Fish protein hydrolysate (FPH) is a powdered product, typically cream in colour. It is produced by the use of enzymes to break down fish proteins into amino acids (proteolysis). The resultant product is highly functional, contributing whipping, gelling and texturing properties when used as an ingredient in food products. Unlike silage production, specific enzymes and/or microbial starter cultures are added to the fish to accelerate proteolysis. Digestion parameters such as time, temperature and pH are tightly controlled to produce FPH with the desired properties.

FPH is not considered a viable disposal route. It is a favourite of academia due to its interesting properties but unfortunately its bitter flavour and fishy odours and flavours make it unsuitable for use in human products. Much unsuccessful research has been carried out to remove these undesirable components, but even if this is achieved, it is unlikely to be able to compete on price with the similar products of vegetable origin which are already in widespread use. The concern over introducing fish allergens into food stuffs is an issue of major concern to end users.

2.2.5 Enzymes

An enzyme is a biological catalyst which can be used to speed up a favourable chemical reaction. A range of protease (protein splitting) enzymes including pepsin, trypsin, chymotrypsin, collagenases and calpains can be extracted from the gut and viscera of demersal and pelagic fish, cephalopods and shellfish. Fish enzymes have many commercial applications due to their unique characteristics which enable them to work at low temperatures and a range of neutral to alkaline pH values.

Enzyme extraction involves mincing the fish, followed by repeated centrifugation and precipitation to remove solid material and concentrate the enzyme, before final purification using ultra filtration and drying to stabilise. Another method involves recovery from silage made from whole cod viscera.

In Norway and Iceland and France, enzymes are currently commercially extracted from cod viscera. No UK producers are known.

Economics and scale

Establishing an enzyme production plant from scratch would require substantial investment in a large scale facility. Enzymes are a valuable commodity. Atlantic cod trypsin costs approximately £60 per 5mg

SWOT analysis

Strengths	**Weaknesses**
• It is expected that the demand for these unique enzymes may increase in the future as further work into biotechnology continues. • Not currently carried out in UK • It is likely that the viscera of most other species of larger fish could also be used as a source of raw material • Maximisation of raw material currently disposed of at sea • Much lab based R&D work has been done • High value product	• Limited access to raw-material as stomachs and viscera are currently disposed of at sea • To achieve maximum enzyme extraction from the raw material, it is vital that the viscera are processed as soon as possible after removal, as spoilage will reduce the quality and yield of enzymes • Some raw material may only be available seasonally • Preconceived ideas about odours. • Only utilises a small amount of the waste • Expensive and difficult to achieve • No commercial extraction carried out in the UK • Need to find uses for large amount of resultant organic waste
Opportunities	**Threats**
• To develop collection and transport links for gut material • Extraction of other niche products	• Cheaper production in the Far East

Conclusion

Enzyme production has the potential to be a lucrative utilisation route. Opportunities exist to collect and transport the gut material and work with an existing biotechnology company to produce the enzymes. In addition, the business could also produce other valuable products from this waste including omega 3 rich oil and other pharmaceuticals. Each new venture would have to be carefully assessed on its own merits using a detailed cost-benefit analysis. Established markets already exist, along with the potential developing new niche markets. A key part of the study would be to focus on identifying these markets, and establishing prices for products and production costs, including finding markets for the resultant waste.

The timescale for setting up a primary product recovery operation should be relatively long 3+ yrs, depending on products produced. This is not an option that a processor would carry out in-house. A regional facility, incorporating other utilisation routes could be possible although this is a highly specialist field. As the process only uses viscera as the raw material and produces a large amount of waste, it is not considered to be an effective solution for industry as a whole.

Fish leather

Fish skins can be processed in the same way as terrestrial animal skins to make leather. Fish leather is supple, soft, breathable, strong and often attractively patterned. Larger fish are more suited to leather production due to the size of the skins. Common sources of leather include shark, salmon, ling, cod and hagfish skins, which are used to make clothing, shoes, handbags, wallets, belts and other small items. Currently there are a significant number of companies in Alaska, Canada, North America and Korea advertising fish leather products on the Internet.

Leather production is seen as a niche option and is not considered viable for industry on a wide scale. There may be opportunities to develop in conjunction with other options (e.g. edible products facility) but it is not seen as a primary solution to seafood waste disposal. If it was to be evaluated, it would be classed as a long-term option.

2.3 Recycling opportunities for shellfish waste

2.3.1 Crustacea shell based products including chitin, chitosan and pigments

Chitin and chitosan can be used in a wide range of different products and the end use will dictate the nature of the plant and the process.

Pigments are produced as a by-product of the process. They are largely used in aquaculture feed and must be produced using an approved method in a plant licensed for the purpose.

If the chitin and chitosan are used in other products such as water treatment or odour filtration systems, these would be classed as technical uses and would require the plant to be licensed as a technical plant, using an approved process. Plants producing chitin, chitosan and pigments from crustacea waste would require approval under ABPR.

Crustacea contain 14-35% chitin on a dry weight basis. Potential sources of chitin, chitosan and pigments include *Nephrops norvegicus* and crab which are available throughout the UK. *Nephrops* are largely concentrated in Northern Ireland, South and South-West Scotland whereas crab waste is much more dispersed throughout the country. The amount of chitin which can be extracted from UK caught *Nephrops* is lower as the head and claws are discarded at sea.

The process involves finely grinding the shell and extracting the pigments into a non-polar solvent. The ground shell is washed with dilute acid and alkali to remove non-desirable proteins and minerals, leaving chitin. Chitin is converted into the more valuable chitosan by washing in concentrated alkali at high temperatures.

Biological methods, using enzymes to break down the shell, can also be used and have been relatively successful at producing chitin. Biological conversion into chitosan has proved more difficult.

Chitin and chitosan have potential to be used in a significant number of products from waste water treatments through to edible products. Pigments are largely used in aquaculture feed, with naturally sourced pigments being in demand.

Other valuable chemicals can also be extracted during the chitin and pigment extraction process.

Economics and scale

The actual cost of establishing a facility to produce chitin, chitosan and pigments is unknown however it is recognised that it would require significant investment, regardless of the method used. As the costs are significant, it is not thought feasible for a processor to establish their own facility.

In the case of the enzymic extraction method, a project in Northern Ireland evaluated the production costs as being in excess of the sale costs (Ref 12).

Product value can be considerable depending on the grade of the finished product. Purified chitin powder can cost up to £50/g. Purified pigments sell for over £100/g at retail prices.

The facility would have to be large-scale to process enough material to make extraction of the different components viable. The potential for establishing such a facility has been evaluated by Scottish *Nephrops* processors who found that they would need a centralised facility to process all the Scottish *Nephrops* shells. However a centralised facility would impact on transport costs.

If processors had to invest in a facility to pre-treat the shell on site, such as drying and grinding, then this would be significant cost. It is known that two Scottish *Nephrops* processors have established on-site drying facilities to preserve and stabilise their shell waste with a view to supplying suitable markets. One has since experienced technical difficulties and is no longer operating the plant whereas the second is still in operation but experiences difficulties with developing markets for the products. A Scottish crab processor obtains material from a number of sources, dries and grinds the shell into a powdered product for export. In this case the company is producing a successful product. There is also a company in York that wishes to source ground crab shell but who experiences problems with supply.

SWOT analysis

Strengths	**Weaknesses**
• Significant demand on a world-wide basis • Extremely valuable finished products • Can utilise all forms of crustacea waste • Lots of background research on the process and end uses	• Expensive extraction processes • Competition from other countries who can produce much cheaper (albeit variable quality) • Produces significant amount of waste which will require disposal (i.e. calcium carbonate) • Complex process requiring specialist skills • Health & safety concerns • Little commercial reality or experience in the UK • Biological system is time consuming (7 days process time) • Difficult to control quality • Ideally requires all Nephrops waste (head and claws) which is usually removed at sea

	• Low quantities of valuable materials in the shell
Opportunities	**Threats**
• Extensive range of possible uses • Cluster of crustacea processors in the UK • Use of *Nephrops* head/claw waste from fishing vessels	• Supplies from developing countries which can out compete the UK • Uncertainty over legalities

Conclusion
This option does appear to be potentially viable but there are a number of issues to address including legality, feasibility, commercial scale requirements, markets, cost effectiveness, suitability and availability of raw material and end product quality.

It is questionable whether industry should establish such a facility itself, as this is a specialised field and should be carried out by companies with suitable experience. It is difficult to see how this would happen without partnership from industry. For a centralised facility, the processing industry would have to agree to process and store the processed raw material to aggregate a batch for transport to the centralised facility. This may require on-site drying. The costs of doing so would have to be competitive with other utilisation and disposal routes.

It is evident that all Category 3 crustacea waste, including processing at sea waste, would be suitable for this kind of treatment. But to make it feasible requires the establishment of a UK based processing facility and the necessary regional infrastructure to support this. This could not happen overnight as all crustacea processors would have to come together to address these issues on a wider scale and engage with relevant companies and organisations. As such it is assumed that it would take more than 3 years to address all the necessary issues and establish this co-ordinated approach.

2.3.2 Mollusc shell based products
Generally, shell is classed as a Category 3 animal by-product and must be handled and treated to the same standards as other animal by-products.

There are exceptions for shell used in certain technical products. A general approval exists for technical plants processing mollusc or crustacean shells from which the flesh has been removed for the production of aggregates, use in gardens, construction, maintenance or repair of footpaths, use in draining the land, and ornamental use.

If a seafood processor wishes to remove the flesh to supply clean shell to be used for these specific purposes then they must contact the relevant authorities for approval (includes SVS and local environmental agency). They must also ensure that whoever receives the shell has the necessary permission for its use (e.g. waste management licensing).

There are a number of potential options for the direct use of mollusc shell including aggregates, mulches and ornamental uses. There are a number of products that can be produced from shell including poultry feed additives, liming agents etc. Companies who require these materials will often specify that they require clean shell. Any company that receives animal by-products for reprocessing, including shell, must use an approved process in an approved facility.

Seafood processors generally produce shell with flesh attached. The remaining flesh can be removed through an appropriate process which could include further manual or mechanical processing including heat treatment, high pressure washing, use of enzymes, bacterial action and acid/alkali washing etc. The process used should be tailored to suit the type of shell and the site. Depending on the end use, the shell may be broken down by milling, crushing or grinding into a range of sizes.

If the shell is used in one of the 5 technical options listed above, there is no requirement to sterilise or pasteurise the shell providing all the flesh has been removed.

There are established practices in industry to heat treat scallop shells for use in product presentation or for decorative products. At the moment this demand is from export markets rather than the UK.

Economics and scale

If clean shell is obtained through normal processing, no further costs will be incurred. However if a secondary flesh removal stage is required the costs will vary depending on the method used. For example, if high pressure water is used this would require the necessary equipment plus manpower, water supply, trade effluent disposal costs and storage. Although these costs would be relatively low, it would still require some investment.

If a more complex process, such as heat treatment, is used this would vastly increase the capital and operating costs. But these costs would vary depending on the process. Therefore it is difficult to put an exact figure on costs apart from indicating this option as potentially low to medium cost. Some of these costs could be recouped if the clean shell is sold for other uses but in most cases it is expected that the seafood processor would pay to cover haulage to the site where the shell is used.

It is possible for a processor to develop an in-house facility to treat their own shell. This would tie in with small-scale, localised uses such as improving land drainage or for footpaths. This is already happening on a small scale in the UK.

Conversely a regional or co-operative development could be undertaken to clean up shell from a number of companies which would require a much larger facility. This would be suitable for something that requires a much larger volume of material, such as aggregates. There are currently a small number of companies taking shell, cleaning it and breaking it down into a powdered product for other uses, including land application, export etc. These have been approved as technical plants with necessary licences issued. Similarly there are also companies who source clean shell for use in their own processes generally on a more localised level. At the moment these companies are charging up to £40/t for shell removal.

SWOT analysis

Strengths	**Weaknesses**
• Basic cleaning can be done in-house by a seafood processor • Can handle a large volume of shell • Can be a low technology, cost effective option • Established precedents in two areas of the UK	• Can be difficult to remove all the flesh from some species • Local markets are not always available or immediately obvious • WMLR may prevent use on land • Processors need space or resources to do it in-house
Opportunities	**Threats**
• Specialist producers already use (imported) shell in a variety of products • Cleaning shell may open up markets for a wider range of products that are not currently accessible • The technical products list can be extended	• Residual flesh if not properly removed could lead to environmental problems • Oversupply of material to local sources/outlets • Undersupply for some potential large scale options such as aggregates

provided it is backed up by evidence of 'no risk'	• Perceptions from environmental health if done in-house

Conclusion
This is a highly practical option for a large proportion of industry providing they have space and resources to do it. It provides an outlet for shell that is currently very difficult to dispose of. The various technical products for land uses are highly practical on a localised level and industry should pursue these further. There is also potential to supply other companies with clean shell, although further work is required to determine supply requirements, technical aspects, markets, costs, suitable technologies etc.

This option could be available to industry in year 0-1 providing they have the background support and expertise to assist them and outlets are available for the products. It is potentially a low cost option available the shell is required for other uses.

2.3.3 Cultch
Cultch is used in shellfish aquaculture as a substrate on which oyster spat can grow. The clean shell (cultch) is laid on the seabed in the area designated for shellfish growing and recognised as being likely to receive larval settlement. After 1-4 years the settled oysters are removed during fishing and the shell returned back to sea.

In 2004, the Marine Consents and Environment Unit agreed that the use of cultch in a shellfish aquaculture facility is not classed as disposal at sea and so would not require licensing as such. However it does require some control to ensure it is carried out effectively. Recently the MCEU, Seafish and the Shellfish Association of Great Britain (SAGB) agreed to develop a code of practice and registration scheme for the use of cultch in shellfish aquaculture.

Economics and scale
Although actual costs are unknown it is considered to be a low cost option as a way of cultivating native oysters. Costs would cover production of clean shell and transport of the material to site. The shellfish farmer would incur costs of laying the material on the sea bed. Cultch is generally classed as a small-medium scale operation, suitable for specific regions where oysters are grown.

SWOT analysis

Strengths	Weaknesses
• Recognised demand • Continuation of an established process • Is legally permitted providing is carried out in accordance with an industry agreed Code of Practice • Increase in spat formation in areas treated with cultch	• Limited number of sites available • Requires clean shell only • Only specific types of shell are suitable • Unknown timescale to agree and develop code of practice and registration scheme • Seasonal demand
Opportunities	**Threats**
• Possibility of accepting a wider range of different types of shell	• Availability of other options may affect long term viability • Potential for polluting or changing areas of the sea bed if not carried out properly

Conclusion
The use of clean shell as cultch is a sensible option for industry but is of limited use because of the few sites available that use it on a seasonal basis. It is difficult to see how cultch could develop more than at current levels. It does not appear to be a suitable route for

resolving the large volumes and range of types of shell produced by the industry. As such, it is a local/regional option, available to a limited number of processors. It is assumed that the people involved in shellfish cultivation are already sourcing the quantity of material they need so whether there is further capacity for expanding this is questionable. Where it is available, it is of vital importance as both a means of utilising shell and growing shellfish therefore the need to develop the code of practice and address unresolved legalities is important. This can be resolved within 0-1 years. Other options such as accelerating recovery of aggregate dredged areas etc need further development and could take 1-2 years to resolve and establish necessary infrastructure.

3. Energy recovery from waste

3.1 Anaerobic Digestion with Energy recovery

Anaerobic digestion is the breakdown of material in the absence of oxygen. It is legally permitted providing that the enclosed reactor is maintained at 70^0C for 1 hour with a maximum particle size of 12 mm across one dimension. Anaerobic digestion facilities must have a pasteurisation phase to ensure that the time temperature requirements are met. There are also wider plant requirements, including obtaining the necessary planning permit from the local council and a waste management license from the regulator.

Facilities are typically operated at mesophylic (25-45^oC) or thermophilic (55-70^oC) temperatures. For mesophylic digestion, biogas production increases up to 40^oC but little above this temperature. Thermophilic digestion enhances performance but requires better control of conditions and more expensive equipment. A third option, often called low temperature digestion or psychrophylic (5-15^0C) digestion, enables simple, low cost, low performance systems to be used.

The quantity of biogas produced from fish waste varies 50-200 m^3/tonne (Jepson 2001). The composition of the biogas depends on the feedstock but typically contains 55 to 75% methane, and the remainder is mostly carbon dioxide.

The type of technology chosen depends primarily on whether the slurry has a high or low solids concentration. The majority of systems in the UK have been designed to treat low solids wastes like animal manures. The load rate and biodegradability will also influence the type of system chosen.

The anaerobic digester can produce biogas that is consumed on site for heating applications. For export and sale of energy the gas can converted to electricity by burning it in an engine driven combined heat and power unit. The electricity can be used on site with the surplus exported to generate Renewable Obligation Certificates (ROC's) and the heat from the engine recovered for heating the digester.

Economics and scale

The economics of digestion are dependent on the returns from treatment such a gate fee for commercial treatment of waste, sale of the digestate products and the value of energy produced.

A facility designed to treat 10-20,000 tonnes per annum may have an average capital cost of approximately £3.25-4.25 million, with operational costs of approximately £100,000 per annum.

Typically in a 600m^3 centralised digester the cost of treatment is £38/tonne. In comparison to aerobic treatment, anaerobic digestion has the advantage of generating energy for the heat treatment sanitisation of the waste to meet ABPR requirements.

The plant must be designed to take advantage of all revenue streams - gates fees, power, heat, electricity and digestate/liquor revenues (even though no net revenue should be expected from the digestate/liquor it avoids costs). To extract electrical power requires a large step up in investment which goes against small scale installations.

Theoretically, anaerobic digestion can be effective at all scales but large scale can take advantage of all revenue streams making the technology best suited on a large or regional basis.

SWOT analysis

Strengths	**Weaknesses**
• Reduced greenhouse gas emissions compared to other waste management options • Suitable for wet waste • Produces a sanitised product suitable for composting/landspreading • enclosed process so emissions are avoided • There is a high degree of process control • Indigestible solids can be removed through settlement • Compliance with ABPR • Generates energy so reduces treatment costs • Excess energy is eligible for Renewable Obligation Certificates (ROC's) • Wastes that have been digested does not emit as much odour • The loss of ammonia to the atmosphere on land spreading is reduced • Nutrients in the digestate are more available to plants.	• fish protein produces high concentrations of ammonia, volatile fatty acids, amino acids and hydrogen sulphide. Ammonia is highly toxic to the bacteria which would digest the fish offal • There is a requirement for liquid storage prior to and post digestion • High capital cost of treatment vessels relative to other techniques • High level of management skills • Limited practical information on performance with seafood wastes • High density shell fish waste may give build up of solid materials at the base of the vessel which are difficult to remove • Obtaining planning permission is a long and protracted process • Waste management licenses and licence to treat animal by-products must be obtained • High transport cost for large volumes of high moisture waste • Must have access to land for recycling • Effect of salt content on bacteria is unknown. • Storage of digestate required prior to land application • Revenue from the digestate unlikely • Collection infrastructure required • Some gaseous emissions are toxic so must be controlled • Currently only 1 commercial system accepting seafood waste in the UK
Opportunities	**Threats**
• ABPR compliance • Generation of energy for use on site • Energy use in the fish processing unit • Rising energy costs • High cost of some other treatments • Renewable energy obligation for large scale operations • Exemption from the climate change levy	• Restriction of access to land in the event of a major animal disease outbreak for spreading of the digestate • Lower cost alternatives. • High level of management is needed • End-product standards required • Increasing legislative costs

Conclusion

In comparison to aerobic treatment AD has the advantage of generating energy for the heat treatment sanitisation of the waste for ABPR. However anaerobic digestion is not considered an individual solution. It is only suitable on a regional basis requiring a large facility capable of treating a mixed waste stream. These are best operated as generic waste management businesses. Therefore this solution will be reliant on the development of centralised anaerobic digesters. The timescale for procurement and construction of large scale digesters is 2 – 3 years.

3.2 Incineration with Energy Recovery

Incineration with energy recovery is the controlled combustion of waste. During incineration, waste is combusted in a purpose designed biomass combustor. Other combustion can take place as part of industrial processes in cement or aggregates manufacture. The heat is recovered indirectly through heat transfer into steam or hot water for process, power or district heating. Steam can be used in a combined heat and power system to generate electricity. The heat from the condensers can be used for district heating or feedstock drying. Waste incinerators with heat recovery are operated at several sites taking local authority and trade waste.

Direct recovery of heat is possible through the use of the hot combustion gases in thermal processes, such as aggregates drying or cements manufacture. For this latter process the effect of the products of combustion on the product produced is a factor in considering the suitability of the fuel.

There are a number of regulations which apply to incineration including waste management licensing, waste incineration directive, pollution prevention and control, Renewable Energy Obligation and Climate Change Levy as well as animal by-products legislation.

Economics and scale

For a medium sized incinerator of 300 kg/hour the cost of the incinerator and associated buildings is £210,000. The typical charge for waste placed into incineration varies from £38/tonne for highly combustible dry wastes to £100 /tonne for wet waste. This is additional to the cost of transport of the material, which can amount to £40/tonne for a carriage distance of 100 miles.

The additional equipment required for emission control and monitoring for compliance with the regulations means that only medium and large size installations are likely to be economic.

SWOT analysis

Strengths	**Weaknesses**
• The nitrogen in the wastes is removed in the flue gas. • There is a large reduction in mass and volume with only the ash left. • The ash concentrates the inert materials that can be used as products, recycled for agricultural benefit or placed into landfill.	• Seafood wastes containing water are not readily combustible. The moisture content of the wastes is high and the organic combustible component of the waste is low particularly for shellfish. • The shell content of the waste means that the residual volumes are much greater than for biomass fuels. The net result of these two effects is that the

	recoverable energy from combustion will not exceed the amount of energy that is required to remove the water and heat the solid material to combustion temperature. This means that a secondary fuel such as gas is required to achieve combustion and maintain the furnace temperatures that are required to meet the waste incineration directive. • The transport system and handling up to the combustion process must comply with ABPR. • Disposal of ash
Opportunities	**Threats**
• The high shell content of whelk and scallop waste may yield ash that can find application in aggregates or chemical applications.	• The high pH of the ash can give handling difficulties. • As the shell content is high and the period of combustion can be relatively fast it is uncertain whether the process will meet the ABPR for use of the solid product.

Conclusion

The capital cost of the plant and the low energy content of the waste mean that the construction of a waste to energy combustor for finfish and shellfish wastes will not be an economic proposition. Neither will this type of waste be attractive to sites where wastes can be co-combusted unless a substantial gate fee is paid.

3.3 Biofuel Production

Biodiesel is the name for a variety of ester-based oxygenated fuels made from soybean oil, other vegetable oils or animal fats. Biodiesel is made through a chemical process called transesterification whereby the glycerine is separated from the fat or vegetable oil. The process leaves behind two products - methyl esters (the chemical name for biodiesel) and glycerine. The process involves drying the oil or fat to remove water. Methanol is mixed with sodium or potassium hydroxide catalyst and the resultant solution is mixed with the oil. After the reaction the glycerine settles and the biodiesel is drawn off and then washed. High technology processing plants have been constructed in central Europe (Company: Biodiesel international BDI). A cottage industry of amateurs exists.

Economics and scale

Cost of production of the biodiesel from oilseed is €0.41/litre (Rice 2003). There are no figures available for seafood but to extract and utilise fish oil would be an expensive and wasteful process.

Centralised large scale plants are required to produce quality certificated product.

SWOT analysis

Strengths	**Weaknesses**
• High value product • Tradable product • Supported by the biofuels directive	• Produces large volumes of waste water • Health and safety issues with small scale systems • Chemical and engineering skills required • No commercial operations in the UK.

	• Limited to oil component of the fish – pre-processing of the fish will be required • Waste cooking oils from processing are more plentiful • The remaining material still needs to be recycled.
Opportunities	**Threats**
• European directive on biofuels requires increasing quantities of biodiesel • In the future construction of biodiesel production facilities in the UK are planned	• Taxation status of the fuel • Health and safety issues from chemicals and explosion • Disposal of wash water and other wastes

Conclusion

Seafood waste contains only a small amount of oil so this solution is not practical for industry in general. There are emerging novel methods of biofuel production involving combined heat and power. These require further investigation.

4. Disposal

4.1 Disposal at sea

Although disposal at sea is not currently permitted under the ABPR it is permitted under the Food and Environmental Protection Act and the OSPAR international Convention, which protects NE Atlantic waters, subject to licensing. Vessels producing waste on board are exempt from controls, however seafood waste from shore based facilities are subject to controls by means of licensing. Licenses are obtained on application from the devolved Government offices. Obtaining a licence requires the completion of a form, which in turn requires the identification of the disposal sites, identification of the nominated vessel(s) and description of the type and quantity of seafood waste for disposal.

There will be requirements for an assessment of the site for its suitability and continuing monitoring to assess the impact in the longer term. The amount and type of initial assessment and subsequent monitoring required is crucially dependent on the nature of the waste and site. Selection of a suitable site is based on logistic factors and physical and biological features together with other site features such as amenity, fishery or nature conservation interests. The key element is to choose a site with a high assimilative capacity. This would minimise the requirement for assessment and monitoring. Much of the initial site selection can be carried out as a desk study as discussed in Mazik et al (Ref 13). The design of the environmental assessment and monitoring is best carried out in collaboration with the relevant scientific agencies (Centre for Environment and Aquaculture Science in England and Wales, Fisheries Research Services in Scotland, Department of Agriculture and Rural Development Northern Ireland).

After a company has a licence approved the seafood waste must be disposed of in accordance with that licence and with the requirements of the ABPR. As such, processing waste should be collected in leak-proof, labelled containers and despatched to the nominated vessel by appropriate transport. The waste must be taken to the designated location and distributed as specified in the original application.

Economics and scale

Licence fees vary between administrations. For England and Wales the fee is £2220, which covers three years; in Scotland and N. Ireland the amount is agreed on a case by case basis. However, the application procedure incurs other costs including an initial environmental impact assessment and ongoing monitoring.

If permission is granted, the licensee will incur additional costs for waste collection, storage, transport and use of a vessel. A company in Scotland, which has recently applied for a licence to dispose of a large quantity of shell at sea, has described it as least favoured option due to the high vessel costs. However, there is no special requirement to purpose design vessels to carry out the operation. Simply shovelling the waste over the side should be viable and concentrated dumping as would be achieved using a specially designed barge should be for most purposes be discouraged. The exception could be where it was intended to aim to dump shell on a particular habitat with a view to habitat enhancement.

The potential scale of operations for seafood waste disposal at sea is much smaller than previous sewage sludge and current dredge spoil disposal activities. Thus impact assessment costs need to be commensurate with the scale of the operation. In order to minimise these costs per operator a co-operative approach to site selection, monitoring and licensing is recommended. It would be envisaged that a group of operators that require site selection and monitoring on a site or series of sites could collaborate in their approach to these assessments. The result of this process could be the licensing of one operator for a site, for example an Association with several vessels being listed as permitted to dispose of waste on that site.

SWOT analysis

Strengths	**Weaknesses**
• Potentially available in areas remote from other disposal methods • Although innovative for Seafood waste disposal, environmental assessment and monitoring costs should be predictable with careful site selection because these procedures are well worked out for other activities.	• Not currently permitted under ABPR. • Potential to have a negative impact on the marine ecosystem if carried out inappropriately. • The process of application for a licence requires an environmental assessment for which a cost is incurred. The outcome of the process is uncertain. • Although the process of environmental assessment and monitoring is well worked out for other activities, application to seafood waste would be relatively innovative. • Only a small number of licences exist in the UK (less than 5); there are not many precedents for this activity.
Opportunities	**Threats**
• International policy (OSPAR 1992) permits controlled dumping. • Enable disposal of wastes in geographical areas where there are no current opportunities for beneficial use. • Potential for some types of waste (e.g. molluscan shell waste) to be used for habitat enhancement and/or seabed replenishment in areas where aggregates have been extracted. • Potential for FIFG funding to cover environmental assessment and limited monitoring costs	• Possibility of negative public reaction and perception. • Potential for adverse effects if disposal is carried out in an inappropriate manner.

Conclusion
This option is most relevant to seafood industry operators remote from facilities for other disposal methods. It would help to address the lack of infrastructure available to shellfish industry in remote locations. This option could be available to industry within 0.5-1 years and would be developed either on an individual or regional basis. The uncertainties over legal differences need to be resolved by the relevant regulators.

4.2 Incineration without Heat Recovery

Waste is combusted in special combustion plant with additional fuel to ensure that the flue gasses achieve the required temperature retention time. The incinerator is fitted with automatic control and temperature monitoring in order to comply with the regulations for a temperature of 850ºC, for two seconds.

Incineration is listed as an approved method for waste treatment under ABPR. There are wider requirements under Integrated Pollution Prevention and Control, environmental protection act etc.

Economics and scale
A medium scale incinerator costs £120,000 but buildings and installation are likely to increase this to £200,000.

Fuel cost for carcass incinerators is £56.60/ tonne with labour and depreciation cost at £54/tonne based on 1000 tonnes per annum. To these must be added the cost of transport for recycling of 50% of the original input as ash for spreading as a liming agent. The break even costs of treatment are £135/tonne for 1000 tonnes and £85/tonne for 2000 tonnes. It is assumed that the recycling costs/value for the ash is neutral.

Small incinerators are no longer exempted from the Animal By-products Regulation. Medium size facilities starting at 2000 tonnes per annum begin to appear economic so are potentially feasible for a region or large company rather than an individual small or medium processor

SWOT analysis

Strengths	**Weaknesses**
• The waste is reduced to an ash that can be landfilled or recycled. • The ash will contain calcium oxide produced from calcium carbonate in the shell during incineration. The calcium oxide may have a market as a fast acting agricultural liming material or perhaps for lime stabilisation of biosolid.	• The high moisture content of the waste will increase the cost of incineration. • High chloride content may increase the difficulty in meeting emission limits. • The high amount of ash from shellfish waste incineration means a significant amount of residue for disposal or recycling. • Co-incineration with other animal wastes may reduce the recycling options.
Opportunities	**Threats**
• Supply of materials to existing animal carcass incinerators would avoid capital spend. • Specialist use of calcium oxide (quicklime) as a fast acting agricultural liming material or for lime stabilisation of biosolid.	• Investment in facilities without secure contracts would be vulnerable to undercutting by other facility providers. • Quicklime is unsuitable for recycling onto established crops or grassland as there is a risk of scorch.

Conclusion

The high capital cost of setting up the incinerator will be a significant barrier to adoption of this technology. The process would have to compete with other cheaper methods of treating the waste to a standard that is acceptable under the ABPR for recycling.

Incineration is considered only for the most difficult category 1 and 2 wastes. Category 3 seafood waste can be treated in simpler heat treatment, composting or anaerobic digestion processes that do not require as much regulation, and produce fewer emissions. The added value of producing a quick lime product has not been determined. The most likely application is in remote areas where treatment and recycling to land is difficult and competing methods are not present.

Appendix II – Suggested actions for each seafood waste management option

Short term options

	Option	Proposed actions	Who
All seafood	Develop regional infrastructure for improved collection and transport to companies that currently pay for seafood waste (including fishmeal, pet food, existing users of shell)	• Identify all routes that currently pay for seafood waste (largely fishmeal) • Ascertain their need for additional raw materials • Organise industry and logistics to collate this material for sale to these routes • Involves Seafish, regional groups and relevant companies to develop this option	Seafood industry Industry representatives Regional groups
	Direct animal feed particularly bait	• Ensure opportunities for bait are maximised by developing links between catching and processing sectors	Seafood industry Regional groups
Finfish	Edible products	• Review technical requirements, range of possible products, costs and potential markets • Carry out a demonstration project to assess feasibility • Develop links between potential suppliers and markets	Seafish Industry regional groups
	Ensiling	• Review Scottish based infrastructure for ensiled material and its longer term feasibility given reliance on exports • Ascertain potential for obtaining material from different sectors of the wild caught industry • If deemed feasible, ascertain how industry can tie in with this option (particularly for Scottish companies) • Provide guidance for industry	Seafish Ensiling companies Industry
Shellfish	Landspreading	• Clarify specific requirements for landspreading shell waste • Develop a practical project to further assess the feasibility of this option which will include identification of the benefits of applying different shell types to land • Disseminate to industry • Regional groups to bring together seafood and agriculture industry in key target regions to develop this option further	Seafish Shellfish industry Land based industries (notably agriculture) Soil scientists

	Technical routes for mollusc shell	• Review current options for utilising shell to make them more widely available • Identify readily available processes for cleaning shell & carry out any required practical work on shell cleaning • Identify any other companies or sectors that could utilise shell and try to develop these options further • Develop regional initiatives for technical routes by bringing industry and potential users of shell together	Seafish Shellfish industry User groups Regional groups
	Incorporate disposal at sea as an interim disposal route	• Address legislative differences between disposal at sea and ABPR • Agreement from regulators on a standardised protocol for applications including environmental impact assessments and monitoring • Seafish to assist with two disposal at sea applications to test the standardised protocol • Seafish to develop guidance for industry and disseminate	Seafish Regulators FRS, CEFAS, DARDNI
	Cultch	• Address outstanding legislative issues (between Gov departments) • SAGB and Seafish to develop required Code of practice • Review recent work on cultch and promote results to industry (shellfish groups) • Develop links between shellfish growers and processors	Seafish SAGB Shellfish industry

Medium term options

	Objective	Proposed actions	Who
	Autoclaving and mechanical and biological treatment	• Review these options in terms of requirements including technical, equipment, legal, costs and uses for treated material • If required, carry out a demonstration project • Review results and promote to industry	Seafish Seafood industry Waste management companies Equipment manufacturers
	Soups, stocks and sauces	• Review these options in terms of requirements including technical, equipment, legal, costs and markets • If required, carry out a demonstration project to assess feasibility for industry • Review results and promote to industry	Seafish Food technologists Seafood industry Equipment manufacturers
Finfish	Fish bones	• Establish collaboration between relevant companies to evaluate this option and address any hurdles • Consider this option as a bolt-on to the earlier work on edible products	Seafish Seafood industry User groups
Shellfish	Crustacea based extracts	• For the range of possible extracts identify their current supply and availability in the UK and how these may be extended by utilising UK sourced material • Assess feasibility of developing UK sources of extracts by evaluating the range of options for infrastructure and logistics • Will require bringing crustacea industry and potential user groups together on national basis	Seafish Seafood (crustacea) industry Equipment manufacturers User groups Transport and logistic specialists

Long term options

	Option	Actions	Who
All seafood	Rendering Composting Aerobic digestion Anaerobic digestion Alkaline hydrolysis Fertilisers and soil conditioners Pharmaceuticals and cosmetics Leather Incineration (with or without energy recovery) Biofuels	• Review these options in terms of requirements including technical, equipment, legal, costs and uses for treated material • Carry out demonstration projects where required • Review results and promote to industry	Seafish Seafood industry Waste management companies Equipment manufacturers Specialist companies
Finfish	Fishmeal Collagen and gelatine Fish protein concentrate Fish protein hydrolysate Leather	• Review these options in terms of requirements including technical, equipment, legal, costs and uses for treated material • Carry out demonstration projects where required • Review results and promote to industry	Seafish Seafood industry Waste management companies Equipment manufacturers Specialist companies

Appendix III – Suggested regional action plan

Regional action plan	What is involved	Suggested way forward	2005 Apr-Jun	2005 Jul-Dec	2006 Jan-Jun	2006 Jul-Dec	2007 Jan-Jun
Collaborative group		Regional group should include local authorities, seafood and waste management industry, funding bodies, regional development agencies, regulators, other food processors if applicable					
Engagement of key/interested partners	• Bring relevant partners together to develop the way forward. • Establish aims and objectives for the region (i.e. does the region want to achieve compliance or move up towards significant & profitable return)						
Develop & deliver action plan							
Assessment of regional situation including barriers	• List all seafood companies in the region. • Quantify waste streams by types of waste produced. • Identify current waste management routes and existing solution providers • Identify long-term regional strategy for waste and timescales involved • Collate information to provide overview of the current situation and priorities	Carry out a survey using information produced by collaborative partners. The results of Section 3 in this report can be used as a basis.					
Options appraisal	• Identify options available to the region • Rank options in order of priority & feasibility • Produce a short-list of preferred options • Identify any interim measures required and any gaps in the available information for the preferred options	Look to the results of section 4 in the report for an overall list of options and their potential availability in the short, medium and long term. Use this as a basis for decision making in the short, medium and long term.					
Action plan	• Bring together necessary expertise and partners • If available, establish links with any	Based on the results of the two previous stages, collaborative group to develop a targeted action plan for					

	existing solution providers to develop contracts for waste management • For the preferred options, carry out further assessment of their feasibility for the target area • Carry out a demonstration of the preferred options to assess feasibility for the region, include cost benefit analysis etc	the way forward for the region. Can use the information in this report as a basis.					
Financial resources for action plan secured	• Identify sources of potential funding and develop application	Collaborative group to review funding options available and apply for funding to deliver the action plan					
Implement compliance projects							
Compliance projects completed	• Use the basis of the demonstration projects to develop successful options into commercial reality and establish contracts	Collaborative group and partners within the project to try to implement the option for the overall region					
Review stages							
Review progress	• Carry out a review of progress	Collaborative group to review progress and update action plan					

