SECTION 5 – SEAWEED / ALGAE CULTIVATION AND UTILISATION

5.1 Introduction

Aquaculture includes the production of seaweed, however, for the purposes of the Jersey Aquaculture Strategy the wild harvest of seaweed is also considered as there are a number of cross-linkages. Furthermore, there is also a pressing need to utilise wild seaweed stocks (beach-cast or harvested) in supporting any potential ormer culture. There may be some scope for seaweed culture, particularly if produced as part of a polyculture system with other aquaculture species. This could be particularly relevant if seaweed production were to be used as direct feed for ormers (see Section 4). A cottage industry for other seaweed products might face difficult challenges both due to the short harvest season and because of the expense of obtaining a land based processing facility. However niche and sometimes high-value markets do exist for edible seaweeds and for other uses such as health treatments and products. The potential for the sustainable exploitation of the Island's seaweed resource in this respect would therefore seem worthwhile investigating.

Seaweed culture is beneficial to the marine environment both in its role as a natural biofilter absorbing nutrients which might otherwise contribute to such things as harmful algal blooms, but also in the provision of shelter and a habitat for other marine life. In addition, culture infrastructure such as long lines provide a deterrent to mobile fishing gear thereby also providing protection of benthic habitats. This can be beneficial to marine conservation objectives and may also help to provide a refuge for larval or juvenile fish and other marine organisms.

Seaweed culture might be complimentary to cross-sector initiatives with energy producers from wind, wave or tidal current schemes (see Section 4). It is possible that future energy schemes might seek to employ seaweed culture to help mitigate their impact.

Algal culture for waste water scrubbing and as biomass for power generation has also been incorporated into this report as seaweed has been proposed for both of these potential applications.

5.2 Seaweed / Algae Cultivation

The culture of algae is a major subject in its own right and as such it is beyond the scope of this report to review this discipline in detail.

Seaweed culture appears to fall into three main areas:

- **Culture for seaweed production**
- **Culture for nutrient scrubbing**
- **Culture for biofuels**

The problems of seaweed cultivation are considered in Section 5.4.5.

5.2.1 Seaweed Culture Optimised For Production

Seaweed culture from tetraspores to produce germlings and the subsequent culture to harvest is a complex subject beyond the scope of this report. The success of developing seaweed culture in Jersey would be strongly dependant on support from associated academic institutions. Nationally, CMar in Northern Ireland and SAMs in Scotland have undertaken comprehensive seaweed work whilst both Portsmouth and Plymouth Universities also have seaweed experts.

Monterey Abalone Company in California has been culturing the red abalone (*Haliotis rufescens)* since 1992 utilising locally harvested giant kelp *(Macrocystis*) (www.montereyabalone.com). A number of claims and counter-claims have been made regarding the sustainability of this feed source and as such the company has developed a proactive collaborative research programme into rope culture with Mike Graham of Moss Landing Laboratories. Fish Farming International (2007) reports that Graham has worked with *Gracilaria pacifica* and *Gracilariopsis andersonii* which are suitable for vegetative propagation and have grown well on 10m rope lines placed offshore of Monterey Harbour. Growth trials at a variety of depths have established an optimum depth at ~3-3.5m which gives good growth (up to 17cm in 2 weeks) without excessive epiphytic growth. Research is ongoing with a second phase of research in 2006-2008 which included the optimization of production and linking production to the support of commercial abalone production. The company is activity marketing the apparent improved shell colouration resulting from the diet.

In common with California, Chilean production of *H. rufescens* has a similar pattern of shifting food sources between wild harvested *Macrocystis* and cultured *Gracilaria*. Flores-Aguilar *et al.* (2007), report that the wild harvested kelp disappears in the winter forcing producers to use cultured *Gracilaria*. This stock is twice the price of the wild kelp and is claimed to yield a slower growth rate. Seaweed culture developments in Chile are reviewed in Buschmann *et al.* (2005).

In recent years comprehensive studies have been performed in both France and in Northern Ireland looking into longline cultivation of *Palmaria palmata* in terms of both its technical and economic aspects. The work by CMar at Portaferry has compared longline productivity and economics for both seedlings and tetraspore techniques and provides a comprehensive model for seaweed production. The work recently conducted at SAMs in Scotland takes this a stage further by growing *Palmaria* longlines alongside salmon pens to aid with nutrient scrubbing, as considered further in the following section.

As mentioned in Section 3, one possible development in this respect at the time of preparing this Strategy was a report that trials using steel 'staple' trestles to grow seaweed had yielded some promising results. Reasonable levels of seaweed have been produced of a species that would be suitable for use in ormer culture (T. Legg, pers. comm.).

5.2.2 Seaweed Culture Optimised For Nutrient Scrubbing

The use of algae for the scrubbing of nutrients from fish farm effluent has received attention from a number of workers in different areas of the world. This system clearly has the benefit not only of removing potential pollutants from receiving waters but also of providing a ready supply of feed material for other species (Section 5.4.2).

Pioneering research work at Woods Hole into integrated aquaculture systems based on human derived waste water was conducted by Rhyther *et al*. (1975) and La Pointe *et al.* (1976) using a combination of micro and macroalgae for nutrient scrubbing. Algae produced was fed to a variety of finfish, crustaceans and molluscs. Abalone inclusion into this multispecies system was also considered by Tenore *et al.* (1973) with three species of abalone feeding on *Ulva* cultured within the system.

The use of macroalgae for nutrient stripping has also been considered with great progress by workers in Israel into nutrient stripping of waste water from sea bream ponds using *Ulva* (Cohen & Neori, 1991; Neori *et al.,* 1991). Research by this group in association with SRL Carna (Ireland) extended to polyculture with the ormer although performance in temperate climates was not considered as effective (J. Mercer, pers. comm.).

Work with *Ulva* and abalone is still ongoing as described in Fish Farming International (2007) for the abalone hatchery at Danger Point South Africa. Consideration of the use of Ulva as an abalone feed following nutrient scrubbing is considered further in Section 5.4.2.

Briggs and Funge-Smith (1993) also considered the use of *Gracilaria* as a potential means of effluent scrubbing for shrimp pond effluent although later work demonstrated the difficulties of algal culture in heavily loaded effluent (1995). *Gracilaria* has also been used in integrated salmon culture trials in Chile. In this case the nutrient scrubbing capacity has been associated with the production of a seaweed product with a higher agar content (Buschmann *et al.*, 2005).

Nutrient stripping on a commercial scale for a salmon farm in Oregon using raceways was undertaken using a red dulse seaweed (Fish Farming International, 1992). Operations were extended to incorporate clams and then abalone to mop up weed production (Section 5.4.2).

BIOFAQs (BIOFiltration and AQuaculture) was an EU project led by SAM's at Oban running from 2000 to 2003 that aimed to evaluate the effectiveness of 'biofilters' (biological filters) on reducing the environmental impact of intensive mariculture (www.sams.ac.uk). SAMs are currently working on seaweed mitigation of aquaculture nutrient input with a view to then feeding the enriched seaweed to herbivores such as urchins or abalone.

SEAPURA is another related EU project that aims to evaluate species diversification and improvement of aquatic production in seaweeds purifying effluents from integrated fish farms. This project ran from 2001 to 2004 and involved the Queens University (CMar) group with Lynn Browne who performed the *Palmaria* longline work mentioned in the previous section. Other species included *Gracilaria* and *Ulva* whilst project work included studies of nutrient uptake rates, the use of weed for finfish feed and husbandry techniques to improve process control. One such measure included the use of low level light to prevent the mass sporulation of *Ulva*.

BIOPURALG is another similar European Interreg IIIC project running from 2004-2006 that aimed to reduce the environmental impact of land based aquaculture through cultivation of seaweeds. The project was run by the MRI (University of Ireland, Galway) with partners in Norway.

In the case of Jersey the limitation of land availability would probably preclude any onshore development although nutrient scrubbing with offshore systems in St. Aubins Bay could be a possibility as considered in Section 5.4.4.

5.2.3 Seaweed / Microalgae Culture Optimised For Biofuel Production

Scotland and Ireland have been undertaking comprehensive reviews of the potential for both macroalgae (seaweed) and microalgae to act as energy crops with culture both on the land and in the sea.

BioMara (the Sustainable Fuels from Marine Biomass project) is a new joint UK and Irish project that aims to demonstrate the feasibility and viability of producing third generation biofuels from marine biomass. The project is investigating macroalgae (seaweeds) and microalgae (single-celled plants) for their potential to provide sustainable fuel. In addition, the project will study the environmental, social and economic impacts of using marine biofuel. Some of the project partners for BioMara have already contributed to a Sustainable Energy Ireland report (Bruton *et al.*, 2009).

Research is ongoing not only into the production systems but also into the harvesting/concentration systems which will also be important. In the short term utilisation of algal to produce biogas through anaerobic digestion is probably simpler to achieve. This is well illustrated by the algae biofuel developments at Santa Rosa where the extensive semi-desert area in the vicinity of the Laguna Beach Waste Water Treatment works were used to construct large algae ponds with the intention to both scrub nutrients from the waste water, whilst also producing biodiesel to power the utility company vehicles. The scheme supported by scientists at Sonoma State University (M. Cohen) since 2006 meet with some success but ultimately found that the algae was more appropriate for utilising in the works anaerobic digester to produce methane. One of the key difficulties in trying to marry up the needs of nutrient scrubbing against biofuel production is that in high nutrient levels massive cell reproduction does not necessarily yield a high lipid content.

The potential for biofuels is considered in Section 5.4.3.

5.3 Seaweed Harvest / Beach-cast Collection

5.3.1 Harvesting Techniques

Jersey's extreme tidal range and rocky seabed should be well suited to the sustainable harvesting of a significant seaweed biomass. Seaweed management models and techniques could be developed from those European countries already engaged in this sector – however, it is uncertain that Jersey will have the capacity to rival existing major producers such as France, Norway and Ireland. A major limitation to bulk seaweed production is the reliance on wild harvesting which would now face a significant challenge in the Environmental Impact Assessment stage of planning.

Seaweed harvesting was performed by Richard Tostevin at Rocquaine Shellfish Ponds, an ormer farm on Guernsey, for over 20 years. Locally harvested seaweed was obtained initially by hand cutting, before use of a French Scuobidou system was introduced in the 1990's. Although abalone production was moderate, generally <5 tonnes per year, continual sustainable cropping of seaweed, as monitored by Guernsey Sea Fisheries, was undertaken from the same reef area (R. Tostevin, pers. comm.).

In the UK, and particularly Scotland, there has been a long history of rockweed (*Ascophyllum* and *Fucus*) harvesting in addition to drift collection from beaches for fertiliser. The Scottish industry and management guidelines on fallow periods for *Ascophyllum* and *Chrondus* are provided in the Minch Project (1995). This study found almost complete recovery of the *Ascophyllum* and its associated ecosystem within 5-6 years. However, if *Ascophyllum* is cropped to approximately 20cm it should be harvestable again after 3 years. *Chondrus* can recover from severe harvesting (close cropping) after 18 months, although this is affected by the timing of the harvest.

More recently *Laminaria* harvesting has been undertaken in Scotland by the Orkney Seaweed Company who have consent to obtain 50 tonnes per year which is harvested using a specially designed cutting grab (Milliken and Bridgewater, 2001). The company's web site (www.orkneyseaweed.co.uk) indicates that they harvest just 0.001% of the standing crop.

5.3.2 Beach Cast Utilisation

Drift weed may accumulate either on the surface, along beaches or at depth between rocky outcrops. The advantage of beach drift is clearly its ease of collection (relative to harvest or culture) which must be weighed up against potentially poor quality rotting weed and a possible extensive cleaning requirement for the removal of sand and pests. The advantage of submerged drift is that it is of higher quality being both cleaner and with a greater chance of still being alive. This must be offset against the difficulty in obtaining such weed.

Deposits of the green seaweed *Ulva* (also known as the sea lettuce) have been reported in St. Aubins Bay. These deposits are thought to accumulate as a result of the nutrient input from freshwater and waste water sources and the suitable hydrodynamic conditions which under certain wind conditions allow seaweed accumulation during the summer months i.e. when light and temperature conditions support rapid growth. To date this seaweed has been perceived as a nuisance particularly in view of the 2009 health concerns in Brittany which are outlined in Section 9. It is possible that this weed could also be utilised for agricultural use if it were collected and utilised rapidly. Figure 17 shows systems that can either collect *Ulva* from shallow waters (using a conveyor type elevator) or directly suck and wash weed from the sand using a specially designed vehicle. Appropriate mechanical means of dewatering and cleaning the weed are needed if this material is to be utilised.

Figure 17*. Ulva seaweed harvesting and cleaning (Source: Bruton et al., 2009)*

Harvest of Drift Seaweed in Italy — Amphibious Drift *Ulva* Harvester in France

The potential to utilise beach cast *Ulva* is considered in Section 5.4.

5.4 Development Opportunities and Limitations

5.4.1 Agricultural Applications

Seaweed has been used on Jersey and throughout the world as a fertiliser for many years. Beach cast seaweed has long been utilised in Jersey in the production of early potatoes and this has become an essential component of the Jersey Royal Brand image. Although seaweed utilisation is reduced now relative to historical levels, between 3000-5000 tonnes per year of wrack are still utilised annually (I. Norris, pers. comm.) Some research work has also been undertaken on Jersey to assess the value of seaweeds in suppressing nematode infestation and promoting growth.

Other more refined applications include the processing of *Laminaria digitata* to provide a clear amber liquid used as growth promoters in conventional and organic agriculture and horticulture. These applications developed by the Orkney Seaweed Company followed many years of work by Professor Cliff Johnson.

It has been suggested that *Ulva* is unsuitable as a fertiliser (I. Norris, pers. comm.) although it is uncertain what the problems are and whether they can be overcome. It is likely that *Ulva* will have a high seawater content which would need to be removed, whilst large rotting masses are also likely to generate both hydrogen sulphide and ammonia which would also be harmful to plant growth. However, the high N and P content of the *Ulva* should be beneficial if the weed could be suitably processed. The seasonality may also be an issue as the majority of *Ulva* is deposited on the beaches in the late summer at a time when seaweed application to the land may not be required. Strategy Option 5.1 could include a review of options to utilise beach cast *Ulva.*

5.4.2 Aquaculture Feed

Seaweed is an ideal aquaculture feed for the ormer. Availability of suitable seaweeds throughout the year is one of the major limitations for the development of abalone culture around the world.

Ulva has been used as an abalone feed in Israel and South Africa following nutrient scrubbing (as described in Section 5.2.2). At Danger Point in South Africa the use of this ‘green filter’ is reputed to reduce water requirements and feed costs to the 200 tonne per year abalone production facility. The biofilter is claimed to provide water of sufficient quality to allow a reduction in top-up water or complete recirculation in the event of red tides in offshore waters. Surplus seaweed from the biofilter provides an output with an enhanced protein content (37-58% for *Ulva* and 35-45% for *Gracilaria*) suitable to feed to the abalone. The 1,600m^2 of raceway tanks (x4 tanks) for the seaweed is sufficient to feed 40-50 tonnes of wet weight of abalone and is reported to save the farm ~US$70-K per year. However, there is some uncertainty about the level of seaweed production as Bolton’s (2006) description of integrated aquaculture in South Africa describes x40 raceway ponds producing 960 tonnes of *Ulva* and *Gracilaria* in 2006. Dlaza (2006) reports on the growth performance of these weeds whilst his current PhD work now includes the culture of *Porphyra* for abalone and use as ‘nori’.

Seaweed used in nutrient scrubbing systems are reported to have a good nutritional quality. Levin who conducted the work in 1991 as part of an MSc claimed that the high nitrogen content of weeds produced exceptionally good growth in abalone. The inclusion of seaweed into any polyculture system may be an effective means of nutrient scrubbing while also providing a valuable food source to the ormer or as product in its own right. Work with Oregon University continued with Rosen *et al.* (2000) who studied the nutritional content of *Palmaria mollis* and also showed that growth under a variety of light, flow and nutrient regimes all provided different morphologies of weed. Evans and Langdon (2000) also reported the co-culture of *Palmaria* with the red abalone which aimed to balance the effluent scrubbing rates with the growth rates of the abalone produced. This interesting study also produced very good growth rates of between 3.5 to 4mm growth per month.

A significant problem with drift seaweed is its limited seasonal availability. Much of the South African *Haliotis midae* production is made using beach cast material which is abundant in the spring and autumn but limited in the summer. Francis *et al.* (2007) compared growth rates of abalone subject to starvation periods against stock with an ongoing ration and surprisingly found that they grew as well as the control animals. Indeed because they ate less food their conversion rates were better than the well fed stock! In the UK, attitudes towards the collection of beach cast seaweed is highly variable from district to district and indeed from beach to beach. Some areas actively remove seaweed as a nuisance in tourist areas, whilst on other beaches seaweed is viewed as a vital component of the beach ecology. Clearly the use of beach cast is unlikely to be a suitable sole source of feed unless it could be processed and preserved.

5.4.3 Biofuels

A major problem with drift or cultured seaweed is its limited seasonal availability which would make it a poor sole source of biofuel.

There are various groups of scientists working towards a seaweed and microalgae approach for biofuel production with conflicting claims, some of which are misleading. There is a great deal of microalgae biodiesel hype with claims that microalgae are up to 100 times more productive than other cultivated biofuel crops, that it is about 1,000 times more efficient to produce fuel from algae than from an irrigated crop and on the production rates and costs for photo-bioreactors.

In summary, there is great potential for algal production of biofuels in the future although significant work is still required. In terms of Jersey the biggest limitation is the high land cost and lack of availability which would present a huge obstacle when compared to other settings where land is cheap and the climate provides high solar intensity/duration.

Utilisation of offshore seaweed (either harvested or with beach cast *Ulva* collection) may contribute to any anaerobic biogas production although the economics of this operation may be marginal unless it could be merged with nutrient scrubbing (see Section 5.2.2).

5.4.4 Environmental Improvement

Section 5.2.2 describes the use of seaweed for nutrient scrubbing. There are a number of schemes elsewhere in the world where both seaweed culture and shellfish culture are used to mitigate nutrient loads to the marine environment. The use of N credits and the general benefit to the marine environment through the ecosystem services provided by aquaculture is considered further in Section 10.

Strategy Option 5.1 proposes the set up a working group which can review the utilisation of seaweed resources. This could include an outline assessment for seaweed production in St. Aubins Bay for nutrient scrubbing.

Strategy Option: To establish a Seaweed Utilisation Working Group.

5.4.5 Seaweed Culture Problems

The seaweed industry was worth US$ 6 billion in 2002 with a strong growth rate (reviewed in Buck and Buchholz, 2004). Although seaweed culture is widespread there are some key problems that influence the potential for utilisation:

> **Economics -** Fallu (1991) considers that the culture of seaweed would probably provide a better financial return if produced for human consumption rather than for abalone feed. Indeed the edible species of *Undaria* (for food 'wakame' in Japan), *Gracilaria* (for food and agar production) and *Porphyra* (for lava bread) all fetch good market prices.
>
> **Seasonality -** Conventional seeding of seaweed germlings in the early spring will only generate harvestable biomass in the later summer/autumn. This does not provide a continuous supply of feed material for ormer culture throughout the year. The use of optimised culture conditions (e.g. artificial lighting) within tank culture can help provide material out of season but may be challenging in economic terms.
>
> **Storm Loss -** This aspect will be a major cause of concern for any potential culture in the waters of Jersey. Under ideal culture conditions good growth rates can be obtained. Unfortunately, the best performance from longlines is obtained when biomass levels are high which is also when the risk of storm loss is the greatest. Buck and Buchholz (2004) considered seaweed culture in high energy Northern European waters using 'ring' structures to provide a more stable platform than conventional longlines. Although the technology was successful the potential income from seaweed production was 40 Euros/ring whilst the initial capital cost was 100 Euros/ring (assuming 10 year depreciation). Even accounting for price rises in seaweed this production cost does not include operational costs let alone an allowance for the loss of systems within the 10 year payback period.

Conceptually seaweed culture in an effluent stream is elegant and may reduce costs through the dual role of the seaweed as a nutrient scrubber and feed source. However, even here there are a number of technical and economic issues that require consideration before these models can be applied to an operation in the UK. An outline of some issues is outlined as follows:

> **Process control -** Prevention of seaweed fragmentation which can block pumps and screens leading to husbandry problems. Fragmentation can be due to sporulation (avoided by culture of sterile stock with vegetative reproduction) and morphological adaptation to thin stringy varieties (avoided by culture of separate parent stock in low nutrient conditions).
>
> **Production rates -** The best examples of seaweed nutrient scrubbing are provided from countries with high insolation rates. Inconsistent performance could well be a problem in temperate climates outside of the summer season.
>
> **Biosecurity issues -** There may also be some biosecurity concerns of using seaweed from an effluent biofilter which is then fed back to stock.
>
> **Market issues -** Aside from the perception issues of growing stock in effluent there is evidence that the seaweed produced in this fashion needs to be utilised with care.

5.5 Policy and Legislation

A major legislative hurdle to the utilisation of seaweed is the ancient seaweed law ‘Loi (1894) Sur La Coupe Et La Pêche Des Vraics’ which limits the dates and times when seaweed can be collected.

Questions have been asked in the States of Jersey Parliament as to why it has not been possible to remove the law which is preventing development of ormer farming. In response the Minister stated that the formal application for law drafting time had been requested for 2007 and 2008 but did not gain sufficient priority over other legislation. A request for drafting time in 2009 was again made although it is understood that this again was unsuccessful.

It is understood that the penalty for breaking this law is a minimal fine – however, this can also come at the cost of losing a concession. A review of this law requires urgent attention before ormer culture can proceed an option which might become possible if legislative changes allow the import of ormer seed.

Strategy Option: Update and revision of the seaweed law ‘Loi (1894) Sur La Coupe Et La Pêche Des Vraics’ which limits the dates and times when seaweed can be collected.

A Strategy Option is also proposed to allow industry to help in the prioritisation of legislation submitted for an allocation of Law Officers’ time. See Section 7.3.

Section 5. Strategy Option(s)

Section	Strategy Option(s)	Benefit / Importance	Output or Outcome	Cost or Funding Requirement	Timeframe for Implementation
5.1	To establish a Seaweed Utilisation Working Group.	**Moderate**	Cross department & industry group to explore and fund utilisation options.	**Moderate**	Medium Term – 5 to 10 years
5.2	Update and revision of the seaweed law 'Loi (1894) Sur La Coupe Et La Pêche Des Vraics' which limits the dates and times when seaweed can be collected.	**Moderate**	To allow ormer culture.	**Moderate**	Short Term – less than 5 years

SECTION 6 – WATER QUALITY AND SHELLFISH CLASSIFICATIONS

6.1 Introduction

Good water quality is perceived as one of the strong positive features of Jersey's shellfish industry and would most likely form a central component to any successful brand marketing exercise. However, there are a number of emerging water quality issues of varying significance which threaten to compromise Jersey's premier status.

Microbiological issues are at the forefront in this respect with faecal coliform loads from multiple sources threatening the classification status, whilst norovirus loading from human waste water sources presents a health risk which threatens Jersey's export status. Recent concerns regarding heavy metal contamination in association with developments at La Collette also threaten to undermine the perception of high shellfish quality even if the actual risk is low.

In some respects Jersey has an advantage over the UK as the smaller administrative structure could allow a highly responsive multi-stakeholder shellfish management approach to be adopted. However, Jersey lacks some of the basic legislative regulatory programmes such as the Shellfish Waters Directive which is due to be subsumed within the Water Framework Directive.

6.2 Onshore Contamination Sources

There are a range of microbial contamination sources from human waste water, agricultural and catchment sources. Generally the absence of heavy industry on Jersey limits the inputs of inorganic and organic contaminants with the exception of some potential port related and waste disposal related issues (see Section 6.4).

Table 2 below provides an overview of the relative faecal coliform loading rates from a range of waste water and catchment sources.

Table 2. Summary of potential Faecal Coliform loads for Jersey

Species		**Loading Rate (counts/animal/day)**	**Population**	**Total Flux (count/day)**	
Human		2.14×10^{9}	90000	1.93×10^{14}	*Note 1*
Human	Lower	1.50×10^{6}	90000	1.35×10^{11}	*Note 2*
Human	Upper	6.00×10^{10}	90000	5.4×10^{15}	*Note 2*
Human	Crude	3.0×10^{10}	90000	2.7×10^{15}	*Note 3*
Human	"Storm"	(2 log reduction)	90000	2.7×10^{13}	*Note 4*
Human	"Dry"	(4 log reduction)	90000	2.7×10^{11}	*Note 5*
Bird	(Duck)	1.01×10^{9}	5000	5.04×10^{12}	*Note 1*
Bird	(Chicken-lower)	1.09×10^{10}	5000	5.46×10^{13}	*Note 2*
Bird	(Chicken-upper)	5.46×10^{10}	5000	2.73×10^{14}	*Note 2*
Cattle	Lower	4.72×10^{9}	5500	2.6×10^{13}	*Note 2*
Cattle	Upper	1.65×10^{12}	5500	9.09×10^{15}	*Note 2*

Note 1: Geildreich (1966a) reviewed in Pommepuy *et al.* (2005)

Note 2: Pourcher (1991) reviewed in Pommepuy *et al.* (2005)

Note 3: Modelling values: crude waste water $2x10^7$/100ml, 150L/day per capita

Note 4: Storm load Bellozanne (99% UV reduction)

Note 5: Dry weather load Bellozanne (99.99% UV reduction)

Discussion of the significance of these loads will be provided in the following sub-sections.

6.2.1 Waste Water System

The States of Jersey have invested significant resources on the provision of waste water treatment and sewerage schemes, primarily for the protection of Bathing Water quality, which have vastly reduced the total faecal coliform loading to the marine environment. Despite this however there remains a high level of concern within the shellfish industry that faecal contamination is occurring from either the main outfall from Bellozanne or from Combined Sewer Overflows (CSOs) during high flow events.

Data for this section was obtained from the Liquid Waste Strategy (2010) and a site visit/meeting.

Continuous Discharges – Bellozanne WWTW- Bellozanne Waste Water Treatment Works (WWTW) is the main sewage treatment works for Jersey and handles the waste water from ~90,000 people – the vast majority of the Jersey population with an allowance for 20,000 visitors. For many years Bellozanne was considered a flagship scheme with UV disinfection installed before many plants in the UK and with a final effluent of high quality. In recent years there have however been problems and some effluent quality issues.

Consent Values:

- 125COD:35BOD:25SS @ 95%il
- 375COD:105BOD:75SS @ absolute level

Although BOD:SS consent parameters are now compliant consent Suspended Solids values were failing up to September 2008. There is still however trouble complying with the total N standard (Total N consent of 10mg with a temporary of 20mg/l allowance). The root of the recent problems relates to attempts at trying to reduce the N load with a novel Degremont denitrifying plant constructed in 2002. An unstable filamentous bacteria grew in the plant which compromised plant performance allowing secondary sludge, which should sink, to become 'bulky' and float to form a scum. Staff worked hard to remove scum and try and improve the treatment process but some suspended solids loss could not be avoided. This would not only have allowed a failure of the suspended solids consent but increased the faecal coliform load, partially because the sludge contains high levels of bacteria, but also because the solids reduce the transmittance in the waste water thereby shielding the bacteria from the UV and therefore reducing the efficacy.

In common with most UK treatment plants there are no direct microbial standards for the discharge. The consent has requirements for UV transmittance and 'applied' dose standards ($24mW/cm^2$) although it is understood that the regulator is due to switch to 'measured' dose. It should be noted that at time of visit calculated dose rates were significantly higher than this in order to provide the best quality effluent. Although there is no microbial limit on final effluent the UV dose will generally provide a final effluent of 50/100ml with a faecal coliform target of <200/100ml in order to comply with the Bathing Water quality standard on St. Aubins beach. However, during times of works instability faecal coliform levels of ~1000/100ml were found (D. Berry, pers. comm.). A sample collected from the outfall by the aquaculture industry and analysed by the regulators laboratory had a faecal coliform count of 550,000/100ml. It is not known whether this sample was obtained at a time of storm flow when UV efficacy is reduced from 4log (99.99% killed) to 2log (99% killed) or whether it was obtained at a time of high flow when process stability could have allowed some loss of (sludge). Unfortunately with this type of problem a bulky sludge is most likely to be lost under times of high flow when the normally dense sludge blanket is pushed up in the final settlement tanks by the high flow rate. Maximum solid loss would most likely have occurred during storm flows – which also happens to be the time for potential sewer overflow spills and increased freshwater stream loading.

A small WWTW also operates in Bonne Nuit on the north coast of the Island. This is a small plant with a population equivalent of 75 although even this plant has a UV treatment system. There have been historical process performance problems at this site although it is understood these have been rectified.

Intermittent Discharges / CSOs- As the sewerage network is 'combined' with foul sewerage and surface water it is subject to increased flows during storms when high levels of flow can give rise to a spill. Combined Sewer Overflows (CSOs) are the points at which the system spills.

The Cavern is the main St. Helier storm water storage facility, designed to provide capacity for a 1 in 10 year storm event. The Cavern is actually used x50 times/yr but is very effective in containing most events – however x2-3 spills/yr from the Weybridge CSO do occur. There are anecdotal reports that the Old Weighbridge CSO used to spill ~ 3 times a week. Problems can occur if intense and prolonged rainfall events are experienced (as it takes x3 days to pump the Cavern empty once full).

Analysis of rainfall events and CSO operation by the regulator could only identify one potential circumstance where there may have been a relationship between Weybridge CSO operation and shellfish sample failure. This work did demonstrate a strong relationship between rainfall events and some shellfish sample failures suggesting that riverine input and increased catchment loading were implicated (see Section 6.2.2) (T. du Feu, pers. comm.).

There are x107 CSOs within the complete sewerage system and associated pumping stations most of which will spill through the manhole covers at the station or from the lowest manholes in the sewerage network. Transport and Technical Services have undertaken a large amount of work in improving the sewerage system on the south east corner of Jersey to prevent CSO spillages. Most south east pumping stations have 24hr DWF storage capacity and Transport and Technical Services indicate that overall there are only 1-2 spills/yr from all sites.

Unlike the UK there are no target/design criteria for CSO spill rates in relation to shellfish waters, although it should be recognised that the shellfish water spill criteria (designed to provide Class B shellfish beds) is 10 spills/year – a much higher spill frequency than Jersey already has. As indicated in Section 6.8.2 within the UK there is no commitment to improve sewerage systems to provide Class A quality shellfish waters.

Work is currently underway to reassess the hydrometric sewer flow model and although unverified model results are due shortly the final report is not due until the end of the year. This work includes checks on the levels of the CSO spills as it is thought that even the current low rate of CSO spills may be an overestimation.

Despite ongoing improvements there is evidence that the Cavern storage system is being used increasingly which may be a result of both increasing urbanisation (more hard surface runoff) and climate change (see Section 9.2). Transport and Technical Services have an ongoing programme of resewerage to separate foul water from surface waters which is the main long term strategy to prevent CSO spillages. Sustainable Urban Drainage Systems (SUDS) have been proposed as the most cost effective way of dealing with surface waters and although they are recognised as best practice there has not been a specific commitment to them on Jersey (A. Scate, pers. comm.).

Strategy Option: Storm water and foul water separation such as through the adoption and retrofitting of SUDS (linked to Liquid Waste Strategy).

6.2.2 Catchment Sources

Non-Connected Waste Water- Although the vast majority of the Jersey population is connected to the sewerage network there are a number of ‘tight’ tanks which are emptied by tankers and septic tanks serving private homes. Both have a potential for contributing a limited load with spills during tankering activity and poorly maintained septic tanks/soakaways giving rise to diffuse catchment sources of pollution.

Agricultural- Studies have shown that bacterial loading from streams is directly related to rainfall which strongly influences run off from agricultural land. The March 1995 CREH report ‘Further Assessment Of Non-Outfall Sources Of Bacterial Indicator Organisms To The Coastal Zone Of The Island Of Jersey’, produced by Dr Mark Wyer, Dr John Crowther and Professor David Kay, shows that 70-80% of faecal indicator delivery into St. Aubin’s Bay occurred during times of high flow rates.

Livestock is dominated by cattle, and in particular the dairy herd, which is considered the greatest agricultural faecal load. In recent years there have been reductions in the dairy herd as outlined in Table 3.

Table 3. Jersey dairy stock levels
(Source: J. Jackson, pers. comm.)

Year	Dairy Head	Total Head
2001	4500	8100
2009	3100	5500

Note: 2001/2002 - reduction of ~1,000 head (production) followed by a later reduction by 400 head (production). 2001 total head calculated using 2009 ratio of ‘production’ head to total head

The current dairy population levels have been applied to the faecal coliform load calculation provided in Table 2 which indicates that cattle provide a larger load than both humans and birds. However, the degree to which that enters the marine environment is a function of waste and land management as considered below.

Agricultural faecal coliform sources include:

Slurry- Animal muck, wash waters (parlour wash) and sometimes rainwater on yard surfaces combine to generate a large quantity of watery slurry. As part of the Nitrate Vulnerable Zone work being undertaken within Jersey there has been concerted efforts to try and limit slurry impact upon water courses. The Countryside Renewal Scheme has helped provide dairy farmers with 4 months sludge storage capacity (based on maximum rainfall basis) with all dairy farms due to have implemented the scheme by 2011. The Water Code also specifies organic sludge application rates and seasonal controls (no spreading in October to December).

Muck- Animal dung deposited directly in the fields cannot be contained in the same fashion as slurry. The main controls are therefore to limit cattle exposure to water courses with set animal watering points and fencing along watercourse bands to prevent excessive fouling. Buffer strips along the edges of fields can also limit faecal loads to streams. It is uncertain to what degree these Catchment Sensitive Farming practices have been implemented throughout the Island.

Sewage sludge- The vast majority of the sewage sludge generated at present is lime stabilised (~38% dry solids) which is produced to the ADAS Safe Sludge Matrix protocol in order to achieve a 6log reduction in faecal coliform count. This is a vast improvement on the historical sludge injection of watery sludge at ~2% dry solids which had a higher potential to contaminate water courses. Control of sludge deposition on the land is highly controlled by Transport and Technical Services with exact records of quantities deposited on specific fields. In the future the new EfW plant at La Collette will have the capacity to take any surplus sludge for incineration.

Although accepted that there are controls for the various fertilisers there is a potential disconnect between regulation of agricultural slurry (Environmental Management Department) and waste recycling (Transport and Technical Services) for sludge and green waste/compost. This is compounded by the tenant farming use of land which promotes double cropping over the year and could allow application of x2 different organic fertiliser sources potentially by two different farmers! In effect there are no combined records of treatment per field.

At present the States of Jersey are supporting combined work between Environmental Management and Water Resources Departments to model and monitor two representative grazing and arable catchments. This work has focussed upon nitrates although there has been some measurement of faecal loads. However, due to resource limitations of and the existing laboratory capacity it has not been possible to undertaken intensive storm related monitoring. In consequence, although agricultural loading following rainfall events has been identified as a major faecal source there is a lack of data to quantify potential impact. This catchment modelling could be a valuable tool in trying to better assess agricultural loads to the marine environment for the whole Island. Strategy Option 6.5 proposes an investigation of the various load sources which will require seasonal and dry weather/wet weather components including stream faecal coliform loads over storm events.

Overall the reduced faecal loading from a smaller dairy herd and the number of potential improvements in management of agricultural faecal loads should have helped decrease the potential contamination of watercourses in the last decade. In summary, although agriculture may still be a major contribution of faecal coliform loading to the marine environment it would appear that the overall load should now be lower than historical levels.

Strategy Option: Continued support for Catchment Sensitive Farming.

6.3 Diffuse Offshore Sources

6.3.1 Wildfowl

Birds can have a significant impact upon both bathing waters and shellfish waters as a result of both the high faecal concentration in the faeces and their numbers. Gould and Fletcher (1978) demonstrated that the faecal coliform load in gull faeces was comparable in load to that of a human. Similarly a review of faecal loading rates provided in Pommepuy *et al.* (2005) demonstrated that bird coliform loading rates of ~$1x10^{10}$/day are comparable to those of humans (~$6x10^{10}$/day). This relationship was highlighted by Environmental Protection Department staff as a potential factor in the bathing water guideline failure at Bonne Nuit in 2009. Ironically, the attraction of the Ramsar site area for large numbers of birds could be having a significant impact upon the water quality within adjacent shellfish beds.

A crude comparison of the relative loading rates from humans, cattle and birds for Jersey is provided in Table 2 from which it should be noted that there are a range of loading rates which have been measured by different workers providing an ‘upper’ and ‘lower’ rate which can vary by orders of magnitude. Making a number of assumptions, it would appear that under 'dry' weather conditions peak bird loading (when over-wintering numbers are at their maximum) could exceed human loading and cattle loading. Even under wet weather conditions when cattle and human loads may exceed peak bird loading the proximity of the birds to the shellfish harvest area reduces dilution and faecal coliform die-off rates, relative to more distant sources from Bellozanne, CSOs or streams draining into St. Aubins Bay. However, locally discharging CSOs and streams could still increase non-avian sources of faecal coliforms.

It should be noted that of total wader numbers of ~4,000-5,000 birds only ~1,000 were observed at South Grouville so the Table 2 calculation is probably an over-estimate of bird loads. Furthermore, there are no bird number counts outside the main over-wintering period in November-January suggesting that for much of the year bird numbers are much lower and their relative faecal contribution is reduced.

As described in Section 10.3.1 bird count surveys have suggested that there was a general decline in over-wintering wading bird numbers up until 2004 but since then numbers have increased and are still increasing. Whilst overall bird numbers might be increasing the monthly bird counts conducted by Jersey Birds show a high level of variation which suggests that faecal load could also vary enormously from day to day. Although it is understood that a qualitative gauge of bird levels are now made during regulatory sampling (A. Pinel, pers. comm.) this may not be sufficient to assess any relationship between any sample failures and bird related loading. The lack of data would make it hard to assess specific historical shellfish sample failures with bird loading. To complicate matters it is understood that large numbers of Brent geese can forage in the north of Grouville Bay or move inland and graze on grass which could then contribute to surface water loads.

Clearly, further assessment of avian sources needs to be undertaken and Strategy Option 6.5 has been proposed to try and further investigate the relative catchment loading sources. This could include Microbial Source Tracking allowing genetic profiling of the faecal source which could help apportion avian contribution.

6.3.2 Resuspension

Microbes removed by solids and deposited within estuarine sediments can have prolonged survival for at least seven days prior to reduction to background levels indicating that sediments can act as a reservoir for faecal contamination (Jeng *et al*. 2005). It has been suggested that this phenomena is a function of sediment organic carbon levels (Gerba and McLeod, 1976). The potential for resuspension impacting upon water quality was demonstrated by Le Fevre and Lewis (2003) who showed that elevated *E. coli* levels in surf zones were found to correlate with sediment in the water column associated with wave re-suspension. A study in harbour waters also showed that storm conditions can then re-suspend microbes and impact upon shellfish flesh quality (De Luca-Abbott *et al.*, 2000).

Other than in the vicinity of St. Helier Harbour there are few low energy areas around the Jersey coast where fine organic rich sediments are likely to accumulate. Periodic storms will remove some sediments or maintenance dredging itself can re-suspend material.

6.3.3 Pleasure Craft

Waste water discharge from pleasure craft can have a significant impact on water and sediment contamination. Sobsey *et al.* (2003) studied faecal coliform levels in open and confined marinas. Over a 6 day period covering a holiday weekend a marina in North Carolina reported that the faecal coliform concentration in marina water increased with the rates of boat occupancy during the weekend holidays.

Guillon-Cottard *et al.* (1998) studied the impact of boat occupancy on mussel faecal coliform flesh concentration in Saint Gervais harbour on the French Mediterranean coast. This study also demonstrated that the highest faecal coliform values were generally obtained in the summer and on the holiday weekends and were indirectly associated with vessel use.

In 1996-97 a high profile norovirus infection epidemic occurred in a number of US states which was traced back to Louisiana where the oyster harvesting boats disposed of their sewage directly overboard (Anon., 1997).

The above cases demonstrate that even small quantities of infected material disposed of in crude waste water close to shellfisheries can have a major impact. In high marine use areas, such as the US, legislation such as the Clean Vessel Act and No Discharge Zones have a much greater emphasis on controlling discharge from pleasure craft users and therefore provide a higher level of protection to the marine environment. These included buffer zones of 305m which are employed in the US to separate shellfish waters from marinas (FitzGerald, 2007b & 2007c). Whilst no comparable measures currently exist within European marine waters, Jersey does have a 1 mile restriction from shore on discharges (G. Morel, pers. comm.).

The ICZM proposition (Le Claire, 2008) aims to *"ensure growth in marine leisure is sustainable."* The ICZM strategy also recognises the need to have a better control of vessel pollution sources and to engage the public in this respect. Section 6.4 reviews St. Helier boat use and the low level of utilisation for the waste water Pump Out facility. As even a small number of discharging vessels can have a significant impact upon adjacent shellfisheries there is a need to provide more information to pleasure craft users about the importance of using appropriate waste disposal facilities. It is recommended that the Environmental Protection Department work with the Harbour Authority to add suitable material to the user guide provided to marina users and possibly to provide appropriate signage around the harbour (see Strategy Option 6.3).

6.4 St. Helier Harbour / La Collette

St Helier Harbour and the adjacent La Collette area form the industrial heart of Jersey. The area has historically been formed of made ground where waste has been disposed to form a base for harbour operations, oil storage, power generation and in the future waste incineration.

A key proposal from the ICZM study (Le Claire, 2008) was to "*reduce inputs of nutrients and hazardous chemicals and materials from both land-based and boat-based sources to improve marine and coastal water quality*." The following section reviews the activities within this industrial/harbour area with regard to potential impacts upon the shellfisheries.

Overall marina water quality is reported to be very good with high clarity and observation of marine life (P. Minnack, pers. comm.). This observation was supported by the abstraction of the harbour water for use within both merchant vivier systems and as a supply for Jersey Turbots new facility (D. Cowburn, pers. comm.). It is probable that good flushing due to a high tidal range is instrumental in maintaining good water quality. Testing of harbour water quality is undertaken by the Fisheries and Marine Resources.

A review of operations in St. Helier Harbour was provided by the Harbour Authority (P. Minnack, pers. comm.) as detailed in the following sub-sections:

6.4.1 Marina Pump Out (PO) Use and Future Expansion of Leisure Craft

Pleasure craft can have an adverse impact upon shellfish quality particularly when users discharge waste into the sea without the use of Pump Out (PO) facilities. Investigations into the use of PO facilities in the UK have suggested a very low rate of utilisation (FitzGerald, 2007b & 2007c). Consultees were approached to establish the current status of pleasure craft use and PO utilisation (P. Minnack, pers. comm.) and a Strategy Option 6.3 has been proposed.

- La Collette Basin (local and commercial use primarily); Elizabeth Marina (564 berths); St. Helier Marina (680 berths of which ~400 are resident boats) has 2 big pontoons for visitors.
- Elizabeth Marina (berthing primarily local craft) has the PO facility which has had limited use (there are a few people who stay on board and living on-board is discouraged).
- St Helier Marina (used by visiting craft) used to have PO facility but this was rarely used. This marina has good shoreside facilities which are extensively used. Around 7,000 boats visit each year generally for short durations of ~2 days.
- Modern boats with storage tanks may become more frequent users of the marinas in the future. There is a possibility therefore that PO use/need may increase?
- There are around 400 boats on moorings outside the main harbour e.g. St. Aubins.

Strategy Option: More engagement with pleasure craft users to limit potential waste discharge impact.

6.4.2 Dredging Operations

Maintenance dredging can resuspend a range of contaminants which could impact upon aquaculture businesses although there is no evidence of any previous contamination related problems in relation to St. Helier.

- Dredging is required every 8-10 years and is due again soon.
- Fine sediment does build up in certain areas (particularly over neap tides) which could be resuspended (there is a potential for Weighbridge CSO faecal solid deposition). Old drying harbours tend to get cleaned by the winter swells. During the summer months there is the potential for CSO discharges to accumulate in the mud and then be resuspended in the winter.
- Some deep water berths in the main harbour are cleaned once a year in order to allow access for larger vessels.
- Spoil area is located 2 miles offshore. Under the current legislation the decision as to whether or not monitoring of water quality whilst dredging is required would fall to Environmental Protection. Vivier operators notified so that they can cease abstraction whilst dredging in operation.
- Anti-clockwise water rotation in St. Aubins Bay means that the St. Aubins Harbour accumulates a lot of silt and therefore also requires periodic dredging. In future both harbours might share a dredger allowing more control and removing the need for hiring in vessels.
- In view of concerns in relation to the incinerator construction / ash spills there may need to be increased precautions during the next dredging period (1-2 years time). The Port Authority would be amenable to placing mussel sentinel bio-monitors within the harbour.

6.4.3 Antifouling

Antifouling chemicals can have a profound impact on the marine environment if they are not handled and disposed of in a correct manner. Shellfish can suffer both reduced growth rates and shell deformation although industry representatives indicated that there is no evidence of any suspected antifouling problems (T. Legg, pers. comm.).

- Boats have an intertidal clean down area.
- Major cleaning is done ashore. There is sand blasting area with drainage catch baskets for debris. Some boat parks have concrete pads but not all and so there is some scope for sand blastings etc. to get back into the marine environment.
- New EU Regulations for antifouling have not yet come into effect in Jersey.
- TBT Regulations apply for under-10m boats which cover most of the craft.

6.4.4 Oil Spill

Aromatic hydrocarbons can have an adverse impact on shellfish quality whilst the use of dispersion chemicals in the event of a spillage can also be equally damaging. A review of the historical oil spill status is detailed below:

- Spill plan includes the deployment of containment booms and application of dispersants. Absorbents are favoured for small spills.
- In general only minor spills have been experienced in the past – indeed main concern has been related to landside spills via the sewerage system (Weighbridge CSO – Bellozanne leak from oil tank). Last major spill was ~1996 with a punctured hold on a Ro-Ro ferry- boom and absorbent pads dealt with this.
- There is also a risk of landside spill from the oil storage tank area which due to the permeable nature of La Collette could impact on harbour area.
- Signed up this year to Osram Response in case of an oil spill.
- Plan due to be updated. Plans include emergency contact to all stakeholders.
- Onshore oil spills dealt with by Transport and Technical Services, including beaches.

6.4.5 La Collette Landfill / Incinerator Issues

An Energy From Waste (EfW) plant is currently under construction at La Collette to provide a new power generation facility and to replace the currently inadequate incinerator facility at Bellozanne. The plant and its construction have raised concerns about possible impacts on the adjacent Ramsar site. The EfW plant has been the subject of a review by the Environmental Scrutiny Panel and there has been a request from Ramsar in a letter dated 30 March 2010 for more details about impacts that may already have occurred or that may occur in the future. Members of the environmental campaigning group Save our Shoreline (SOS) feel that the impact of some activities during the construction phase have not been fully assessed and that the potential threats during operation remain unknown (D. Cabeldu, pers. comm.).

It is reported that during excavations into previously tipped ‘inert’ material a section of membrane for the bunded incinerator ash was breached. The permeable nature of the La Collette area allowed a pit within the excavation to fill with seawater which was contaminated by the ash with a high probability of a high heavy metal content. Although quick actions by site personnel limited the extent of ash washed out, a potentially significant quantity of material was released. Transport and Technical Services acted to tanker the contaminated water from the trench for disposal at Bellozanne WWTW – however, there are concerns that it would have been impossible to remove all material. Also, as the excavation pit drained on each low water there was a discharge of potentially contaminated water into the environment. A further major ‘incident’ was reported to have occurred at the end of April 2009 when untreated leachate was pumped out of the incinerator workings with no remediation over a 3 month period.

SOS are also concerned that the construction phase problems with the ash pit may have compromised the integrity of the containment membrane leaving a potential legacy for ongoing contamination to the marine environment through the permeable structure of La Collette.

Monitoring of the marine environment has been undertaken by Fisheries and Marine Resources as part of an ongoing sampling programme monitoring heavy metals at five sites around Jersey coastal waters since 1993. This was implemented in response to ash disposal on reclamation land at the Waterfront. It is reported that seaweed (Fucus) and slipper limpet samples have not indicated contamination (G. Morel, pers. comm. & du Feu, 2009). However, the absence of sampling from commercial species has been criticised and raised questions regarding shellfish quality.

Although the actions undertaken and the potential impact upon the marine environment are beyond the scope of this report it is apparent that there is ongoing potential to damage the perception of Jersey shellfish quality regardless of any actual contamination.

In view of the range of industrial processes at La Collette and St. Helier Harbour and their close proximity to the current aquaculture production area it is suggested that sentinel bio-monitors (e.g. mussels) are deployed in strategic locations around La Collette and St. Aubins Bay. Such a long term chemical and microbiological monitoring programme will help to assess product quality and will provide defensive monitoring.

Strategy Option: Establish sentinel bio-monitoring around La Collette and St. Aubins Bay.

6.5 Shellfish Classification

Shellfish classification under the Shellfish Hygiene Directive (SHD) was drawn up to provide public health protection from the consumption of shellfish which are accepted as being a potentially high risk food. The SHD provides a classification scheme according to shellfish flesh quality – which is in turn largely determined by the quality of the harvest waters which are in turn protected by the Shellfish Waters Directive (SWD) providing a linkage between pollutant loading, water quality and shellfish quality. Both the SHD and the SWD are considered further in the following section.

6.5.1 Historical Classification Status

Jersey has long been known for its good shellfish classification status under the SHD with a high proportion of Class A beds relative to the rest of the UK where Class A beds are rare accounting for around only 1% of all designated harvest beds. The historical largely Class A quality of Jersey's shellfish beds coupled with the close proximity to the large French market have provided a significant advantage to the aquaculture industry. In consequence, the recent downgrade to a number of Jersey's harvest beds is a major threat to the performance of the Island's shellfish industry. There is a widespread perception in the industry that the proportion of Class A beds has dropped in recent years although the States Vet, who are the current responsible agency, state that there have been 9 downgrades and 8 upgrades in the last 10 years (L. Lowseck, pers. comm.).

Shellfish classification used to be administered by the Fisheries Department who, based on the advice of Cefas, adopted a random sampling regime throughout the harvest beds to provide a representative sample and utilised an un-accredited laboratory on the Island to reduce sample transit time. The States Veterinary Officer who currently administers the classification scheme now operate a consistent sampling position on the shoreward edge of the harvest beds, which may well provide a 'worst case' picture of shellfish quality a protocol which is considered consistent with protection of public health.

The States Vet obtains a high level of support and advice directly from Cefas with input into conducting sanitary surveys and participation in harmonised quality control schemes which have led to Jersey utilising an accredited laboratory on the UK mainland for shellfish flesh analysis, which could also have influenced classification results as shown in Table 4.

Table 4. Summary of E. coli data from Jersey classification results (pooled from all sites)

Period (Note 1)	Average (counts/100ml) (Note 2)	Sample No.	No. >230 (Note 3)	% >230	No. >4600 (Note 4)	% >4600
May 2005-Apr 2006	183	102	16	16%	0	0%
May 2006-Apr 2007	95	107	8	7%	0	0%
May 2007-May 2008*	169	117	16	14%	0	0%
June 2008-Apr 2009*	719	197	92	47%	6	3%
May 2009-Mar 2010	572	176	58	33%	3	2%

*Note 1: Data analysed from start of May to end of April (Cefas approach). *New analytical laboratory adopted from June 2008*

Note 2: Data of <20counts/100ml analysed as 10counts/100ml.

Note 3: 230counts/100ml (Class A/B boundary)

Note 4: 4600counts/100ml (Class B/C boundary)

Table 4 demonstrates a marked increase in *E. coli* results corresponding to the transition to the UKAS accredited laboratory in the UK in June 2008. This would support the views of regulators that the recent apparent drop in Classification status is partially a feature of the methodology.

However, the lower quality in 2008/09 relative to 2009/10 (so far) indicates that underlying environmental factors could influence classification. The Environmental Protection regulator has stated that reduced Bathing Water quality in 2008 was a function of increased loading from freshwater sources particularly in association with rainfall events which has also been suggested as a primary factor in the ‘spikes’ of poor shellfish flesh quality. The Environmental Protection Department have produced a series of short reports demonstrating a relationship between rainfall events, water quality and monitoring non-compliance looking at antecedent rainfall in the 96 hour period preceding shellfish failure. These studies also reviewed telemetry results from the waste water system and showed only one case where there was a potential causal link where the Weighbridge CSO outfall from the Cavern corresponded with a drop in shellfish quality at Le Hocque. Other potential contributor factors to reduced shellfish quality samples include high levels of wildfowl associated with deposits of seaweed and uncertainties on shellfish movements/handling at the sampling point (T. du Feu, pers. comm.).

The shellfish industry consider the drop in shellfish classification status to be a function of increased pollution from waste water sources including both local CSO discharges and from the main Bellozanne discharge in St. Aubins Bay. Industry members have obtained their own waste water discharge samples which were taken to the States Analyst and provided a peak faecal coliform count of 550,000/100ml, although this result was not verified and accepted by the Environmental Protection Department as the regulator.

To some degree the concerns of waste water related quality issues have been supported on some occasions by other States departments. The States Vet sampler undertakes visual observations during sample runs and concurs that waste water related material has been observed in relation to spills across the beach which have also been sampled (A. Pinel, pers. comm.). The Public Health Department noted that Microbial Source Tracking work from the south east corner of the Island in 2008 indicated faecal contamination of human origin (S. Smith, pers. comm.).

The Transport and Technical Services Department point out that considerable work has been undertaken recently in the vicinity of the shellfish beds in providing storm water storage to limit CSO spills from the area as described in Section 6.2.1. Transport and Technical

Services have also made significant improvements to the process problems as described in Section 6.2.1. Bellozanne WWTW discharge consent for suspended solids was exceeded prior to September 2008. These episodes would have been accompanied by significantly increased faecal coliform loading from the discharge. The increased rainfall in 2008 will have exasperated the potential level of impact from Bellozanne both by increasing the frequency of storm water passage through the UV plant and the level of solids lost from the unstable final settlement tanks. Ironically, large rainfall events would also have simultaneously increased freshwater loading from the land. In the absence of 'event' related sampling from the watercourses, or secondary dispersion modelling and tracer studies for the plume dispersion from Bellozanne, it is very hard to differentiate between the alternative loading sources. It therefore seems unlikely that a retrospective study could identify a single 'smoking' gun which could have caused shellfish sample failures.

Table 4 indicates that the overall classification status has improved in 2009 which concurs with an improvement in the Bathing Water quality of the Island. There remains a need for ongoing work to determine the potential sources of contamination in relation to shellfish quality as described in the Strategy Options. A concerted study is required to monitor event related impact upon the shellfisheries encompassing both freshwater and waste water sources. If hydrographic studies are conducted in St. Aubins Bay as part of potential modelling work for outfall placement it is strongly recommended that the opportunity is taken to both incorporate microbial parameters within the sampling suite and to including a microbial decay component to the computer modelling.

Strategy Option: Water quality investigations to establish relative risks between contaminant sources.

6.5.2 Implications of Class B Classification

Shellfish Classification under the Shellfish Hygiene Directive forms one of the central aspects to shellfish business success as it dictates both the operational costs (the need for depuration or relaying) and market price (perception of quality).

Bivalve Depuration- As a significant amount of Jersey production now originates from Class B beds large-scale depuration systems would be required if operators were intending to sell stock directly for human consumption. This would impose a significant additional cost and operational burden upon the industry and a considerable planning challenge to obtain landside depuration facilities. Large-scale commercial depuration systems are available and moves are currently underway in the UK to sanction the use of ozone for depuration as is practised in other EU Member States. One possible way of avoiding planning issues may be to consider mobile containerised depuration systems such as those developed by Depur Systems Ltd. (www.depursystems.com) although this would of course add considerably to the cost.

The Island has adopted UK standards for depuration (42hr duration and UV) for product sold locally and into UK using two small capacity systems currently installed in the Island. The Public Health Department were involved in the performance testing of these units and involved in advising on assessing a clean source of seawater water abstraction.

As norovirus depuration rates are significantly slower than those of *E. coli*, research work has moved towards trialling enhanced depuration at elevated temperatures and for extended periods. Doré *et al.* (2003) reported on work Cefas conducted for the Food Standards Agency which proposed a 5 day depuration period. Doré *et al.* (2010) described the successful use of this depuration regime upon contaminated stock from a confirmed norovirus outbreak. Unfortunately, the extension of the depuration period further decreases the throughput of existing depuration facilities which would therefore require an expanded capacity to meet the same throughput. Other researchers are looking at probiotic methods to increase depuration rates (Pommepuy *et al.*, 2003).

Training and support could be provided by external trainers i.e. the Seafish/REHIS Bivalve Purification Operations Course, which is an accredited course leading to a nationally recognized qualification as well as the Bivalve Purification Management course. Also available is the newly accredited Bivalve Purification Inspections Course for Environmental Health Officers. These courses are available through the Southern Shellfish Training Centre based in the South West of England or the Scottish Shellfish Training Centre.

Relay Areas- In the event that shellfish harvest beds remain permanently downgraded there remains the option to relay stock in new offshore Class A areas in order to naturally depurate stock. However, the Seymour Tower bed is currently the only Class A bed which is limited in extent, is not available to all businesses and has limited access due to its significant distance offshore.

Creation of new Class A concessions remains a theoretical possibility although the likelihood of the aquaculture industry obtaining further concessions in the Seymour Tower region deep within the Ramsar site is limited. New offshore concessions in cleaner water could be sought although the industry does not have the infrastructure to operate subtidal culture techniques. Furthermore, increased penetration into waters below MLWS could have implications for vessel navigation which may impact upon pleasure craft and fishing operations.

Off Island Handling- In the absence of dedicated depuration facilities on the Island the shellfish businesses have to sell stock at a reduced financial rate of return in order to allow for the fact that the stock must either be relayed elsewhere or depurated by a third party.

Strategy Option: An evaluation should be carried out for the Jersey shellfish culture sector of the practical, economic and financial implications and impacts between Class A and B status of local waters.

6.5.3 Shellfish Analytical Options

Shellfish analysis for the *E. coli* indicator organism remains the central parameter within Shellfish Classification. Jersey is placed in a difficult situation having to either utilise a local laboratory which is not accredited but which allows a short transit time or to use an accredited laboratory on the UK mainland. As indicated in Section 6.5.1 above the combined data from all Jersey shellfish beds suggests the change in analytical laboratory has had a significant impact on the overall *E. coli* results obtained.

A further limitation to shellfish management is the time taken to analyse shellfish flesh samples with the MPN methodology which can result in a time delay in which any potentially contaminated stock is likely to have reached the market before the analytical results are available, thus providing little protection to public health.

Impedance is a rapid analytical method which can provide a shellfish result in less than 8 hours – considerably less than the 48 hours needed to obtain a confirmed result via MPN. Although the technique has been widely used in the food and biomedical sectors for many years it has only recently received widespread acceptance for shellfish and environmental samples. The French regulator Ifremer has used a rapid impedance technique since the 1990's which has recently been accepted by the Central Reference Laboratory Cefas at Weymouth. This opens the way for the use of the technique not only for end product testing but also for Classification monitoring. The use of impedance has the capacity to revolutionise how samples can be used proactively rather than reactively in shellfish management. It therefore has the capacity to allow effective public health protection.

There may be scope in the future to establish an accredited impedance method on Jersey. In addition, an impedance method has also been developed for Bathing Water samples which would also be of help in shellfish investigations when rapid results are needed. The potential use of the impedance technique on Jersey has been suggested as a Strategy Option.

Strategy Option: Implement Island-based accredited impedance analytical capability.

6.5.4 Proactive Shellfish Management

The Public Health Department previously chaired a local Shellfish Liaison Group with representatives from industry, Environmental Protection and Transport and Technical Services. This group was an example of good or best practice and performed many of the functions expected of Local Action Groups (LAGs) formed in the UK in response to a 'trigger' faecal contamination event. Unfortunately due to staff losses this group has stalled with a staff replacement at Public Health unlikely until the end of 2010 (S. Smith, pers. comm.).

Transport and Technical Services remain willing to engage with industry and share telemetry output (D. Berry, pers. comm.) which is in keeping with the objectives of the Water Framework Directive where all stakeholders in a river basin should have an integrated approach to the management of the marine environment. This attitude is considerably in advance of data sharing on the mainland UK where private water utilities are required by consent to monitor and then report CSO spill status. However this reporting is generally only done annually in the June reports to OFWAT. Additional spill data may be shared for the preceding couple of weeks in the event of a 'trigger' level investigation. However, most CSO telemetry to shellfish waters are not monitored on-line or provided to potentially affected shellfishermen. In the past Transport and Technical Services have invited shellfish industry representatives to Bellozanne WWTW to show the telemetry system in place in order to highlight that any spill potential or works performance problem can be determined on-line (D. Berry, pers. comm.). In order to provide an external expert opinion Professor David Kay from CREH at Aberystwyth University was brought in by the States of Jersey to discuss the results with shellfish industry representatives. CREH have had a long history of work on the Island looking in particular at Bathing Water compliance which has highlighted the relationship between stream loading and beach microbial compliance. Further work needs to be undertaken to build confidence between stakeholders as there remains a low level of trust despite these efforts.

Comprehensive work is currently underway by Transport and Technical Services consultants who are undertaking a hydrometric sewerage monitoring and re-modelling exercise. This should allow a more accurate assessment of potential spill impacts in relation to rainfall events. This in turn may then allow retrospective assessment of historical events (perhaps from the wet summers of 2007 and 2008), or may be of use in helping to forecast potential climate change impacts using output from 'weather generator' simulated storms (see Section 9). An improved understanding of the relationship between rainfall and the potential impact upon the sewerage system could be used to provide an 'early warning' system as with the state of the art CSO system monitoring developed in the US which allows linkage with rainfall RADAR to predict storm water flows.

With a better understanding of the mechanisms operating between environmental loading factors, water quality and shellfish quality it may be possible to develop a proactive shellfish management system. Information sharing by the operator, regulator and shellfishermen could then give rise to precautionary voluntary closures at times of high threat. High rate sampling (see Section 6.5.3) can then be used to provide an 'all clear' state.

A similar approach has long been adopted in the US and Australia with shellfish closures in relation to high riverine flows where there is a known relationship with deterioration in water quality. The US classification system is based upon water quality standards (mean and

10%ile) for ‘Approved’, ‘Conditionally Approved’ ‘Restricted’, ‘Conditionally Restricted’ and ‘Prohibited’ waters according to the water quality status of the shellfish water.

It is suggested that Jersey with its smaller chain of stakeholders is in a unique position to lead the way in Europe in providing a model of integrated proactive shellfish management to meet the needs of the WFD. A Strategy Option has been proposed to assess this potential.

Strategy Option: Develop Proactive Shellfish Management System.

6.6 Microbial Health Risks

6.6.1 Norovirus

Norovirus is considered by the Public Health Department to be a major issue for the Island and to aquaculture industry exports. At present norovirus is not a parameter incorporated within the Shellfish Classification scheme and therefore not routinely tested. However, at a European level it is accepted that regulation needs to move towards a greater emphasis on viral risk management as norovirus and hepatitis are persistent within the environment and not effectively removed by current depuration protocols. In consequence, the European Central Reference Laboratory has recently accepted RT-PCR as an accredited analytical method for the detection of norovirus and baseline work performed by CEFAS is currently underway in x50 oyster fisheries on the UK mainland. A future regulation scheme incorporating norovirus is expected.

Norovirus originating from shellfish is <u>not</u> thought to be a major issue as local shellfish consumption is low and therefore unlikely to contribute greatly to norovirus levels in the Island relative to the known vectors. There is a high incidence of community based infections which do not tend to follow the classic winter vomiting pattern – e.g. summer 2005 outbreak. Tourism and transport have been found to be a major factor in maintaining this pattern with the ferry service and local coaches found to provide a vector from infected symptomatic tourists and new tourists coming to the Island. The Public Health Department has worked hard from 2005 to 2009 with travel operators on deep cleaning programmes to minimise impact. Public Health Department have also worked with hotels on trying to manage this issue following a number of hotel related outbreaks.

It is hard to get a definitive assessment of the level of infection and impact as there is a very low reporting rate – not helped by limited feedback from doctors, exacerbated further as patients are charged in Jersey to see the doctor.

Norovirus contamination of shellfish for export is therefore the prime concern as there is a high rate of viral loading from Bellozanne WWTW and from CSOs when they operate.

Exports of shellfish could be compromised by norovirus contamination;

- Fat Duck incident initially thought to be a result of Jersey sourced oysters (via Maldon Oysters).
- Maldon Oysters supplied with oysters from Jersey and this is currently being investigated as a potential source of an outbreak.
- Scandinavian import rejected due to norovirus contamination.

The winter of 2009/2010 has presented an exceptionally high level of norovirus cases across Europe with around 70 oyster related norovirus cases in Ireland and the UK. Businesses are increasingly turning to self-monitoring to limit expensive product recalls with outbreaks attributed even to Class A shellfish (Doré *et al.,* 2010).

6.6.2 Other Microbial Pathogens

Cryptosporidium– In 2002 x300 cases were reported in association with a swimming pool related incident (private pool fed from contaminated source which subsequently contaminated a number of public pools). No connection with shellfish.

***E. coli* 0157-** No reported cases in Jersey.

Salmonella - Small number of sporadic cases from 1998-2006/7 possibly connected with a local vegetable grower. No connection with shellfish.

***Vibrio parahaemolyticus* -** No reported cases in Jersey.

6.7 Harmful Algal Blooms

Harmful Algal Blooms (HABs) occur when microalgae flourish under optimal growth conditions i.e. when nutrients, sunlight, warmth and residence time are not limiting. HABs can impact upon shellfisheries either directly by killing stock through a reduction in dissolved oxygen levels or indirectly by contaminating stock with poisonous biotoxins with potentially serious or even fatal health consequences for consumers.

'Red Tides' were observed in a number of locations around the South West of England coastline in 2009 resulting in both fish kills and significant stock losses of oysters (Duchy Oysters, pers. comm.). Biotoxin contamination occurrences are also widespread in UK fisheries.

Samples of shellfish and water are obtained for Diarrheic Shellfish Poisoning (DSP), Amnesic Shellfish Poisoning (ASP), and Paralytic Shellfish Poisoning (PSP) testing of which is carried out by Cefas Weymouth. To date all results have come back negative since 2004.

The potential impact of climate change on HABs is considered in Section 9.

6.8 Legislation

6.8.1 EU Food Hygiene Regulations

The EU Food Hygiene Regulations (852 / 853 / 854), which took effect on 1st January 2006, impose specific hygiene rules to protect public health with respect to the consumption of food of animal origin, which includes shellfish. These regulations cover live bivalve molluscs, echinoderms, tunicates and marine gastropods, but not other species such as crabs and shrimp. In the UK these regulations are enacted by The Food Hygiene (England) Regulations 2006. Harvested shellfish were previously classified under the Shellfish Hygiene Directive (Council Directive 91/492/EEC of 15 July 1991) which was repealed in January 2006 (Source: http://www.defra.gov.uk/environment/quality/water/waterquality/shellfish/index.htm). The regulations set standards for the flesh quality of shellfish from designated production areas, which are classified as either A, B or C. The classifications are based upon microbial standards using the *E. coli* content of the flesh and intra-valvular fluids with the following limits:

- Class A - shellfish contain less than 230 *E. coli* per 100 grams of flesh
- Class B - shellfish contain less than 4,600 *E. coli* per 100 grams of flesh
- Class C - shellfish contain less than 46,000 *E. coli* per 100 grams of flesh

Monthly samples are obtained from all harvest beds with according annual classifications. Class A shellfish are fit for direct human consumption, whilst Class B stock will require either depuration, heat treatment or relaying. Class C stock are required to be relayed in an area of higher classification status.

In 2005-2006 many Class B/C harvest areas in the UK with >5 years monitoring data switched to the Long Term Classification (LTC) scheme which was proposed as a mechanism to even out episodic ‘spikes’ for some sites which can demonstrate good long term quality. A range of ‘Action States’ exist under LTCs whereby potential pollution incidents are investigated by Local Action Groups (LAGs) under a Local Action Plan (LAP). Although no shellfish beds in Jersey are currently working on the LTC scheme many of the actions normally expected to be performed by the LAGs have in the past been undertaken voluntarily by States of Jersey officials through the Shellfish Liaison Group. This is an example of good or best practice which would be well worth restoring and formalising.

Strategy Option: Recommence Shellfish Liaison Group.

6.8.2 Shellfish Waters Directive

The aim of the EC Shellfish Waters Directive (2006/113/EC) is ‘to protect or improve shellfish waters in order to support shellfish life and growth, therefore contributing to the high quality of shellfish products directly edible by man.’ The Shellfish Waters Directive (SWD) has been a major driver for improving shellfisheries within the UK although this law has <u>not</u> been enacted within Jersey.

Despite this the Liquid Waste Strategy (LWS V7) highlights a States of Jersey commitment (“2000 and Beyond” and the Environmental Charter of 1996) that Jersey law would require standards at least equivalent to those of the EU. The LWS then listed the SWD as one of the international legislative measures applicable to the strategy.

The SWD includes a variety of mandatory and guideline water quality parameters including a guideline microbial standard of 300counts/100ml faecal coliform standard in shellfish flesh at the 75%ile. Although the SWD microbiological guideline standard is based on a flesh sample it has been necessary to plan scheme improvements on the basis of delivering a water column objective. The Shellfish Water monitoring programme incorporates both shellfish flesh and water microbial samples.

Consent guidance is provided by the Environment Agency (EA) with detailed input from Cefas as a statutory consent consultee to relate shellfish flesh to water quality. This document proposes a mean faecal coliform concentration of 110 *E. coli*/100ml relating to a shellfish flesh quality of Class B. The EA assume parity between *E. coli* and faecal coliforms and utilized a 100counts/100ml faecal coliform voluntary standard. This water column standard has been used as a tool for modelling scheme performance and consent standards for both continuous discharges (5.25log reductions from crude waste water to the edge of the shellfish waters) and for CSOs (<10 significant spills/yr).

The revised SWD in 2006 set Member States a 6 year programme to achieve the required standards. In the case of the UK government there was a commitment in both England and Wales to achieve the SHD Class B standard (EA, 2000) through a programme of scheme improvements with associated monitoring. As Jersey currently only has one Class C area, it should be noted that an equivalent commitment to Class B status in Jersey would not provide a great deal of pressure to drive further shellfish water improvements.

6.8.3 Water Framework Directive

The Water Framework Directive (WFD) is a major piece of legislation which will integrate future surface water environmental issues. The WFD uses a series of chemical and biological indices to provide a catchment based classification of surface waters from headwaters to the sea with grades from 'High' to 'Poor'.

The Environmental Protection and Environmental Management Departments are currently working together to try and establish water quality standards and their potential impact on the sensitive species. A major driver in this work has been concern in relation to nitrate levels in freshwater courses.

However, the WFD will also have a direct impact upon microbiological standards and help protect shellfisheries as the SWD will be repealed in 2013 and incorporated into the WFD. When this occurs, the WFD must provide at least the same level of protection to shellfish waters (which the WFD classifies as protected areas) as the SWD does. Details of how this will be achieved and what standards will be adopted are still being debated. At this stage it would appear as though there will be harmonisation with the Shellfish Hygiene Directive in the use of *E. coli* rather than faecal coliforms and that future designated Shellfish Water areas will more closely match Shellfish Harvest beds. If Jersey intends to implement the WFD there will be a need to designate Shellfish Water areas which could be done on the basis of River Basin Plans from the onset (G. Davies, Shellfish Specialist, Environment Agency, pers. comm.).

6.8.4 Water Pollution (Jersey) Law (2000)

The Water Pollution (Jersey) Law (2000) makes a commitment to no deterioration in water quality levels as described below:

"General objectives of Minister

(1) In carrying out his or her functions under this Law, the Minister shall have as the Minister's general objectives the maintenance and improvement of the quality of water in and around Jersey by the prevention, control, reduction and elimination of the pollution of controlled waters.

(2) In carrying out his or her functions under this Law, the Minister shall also seek to promote the conservation and enhancement of the natural beauty and amenity of controlled waters, their use for recreational purposes and the conservation of flora and fauna that are dependent on an aquatic environment."

Unfortunately, it is unclear what the elimination of pollution and the conservation of fauna specifically means. For example, it can be argued that the Classification status has not greatly deteriorated – yet conversely the *E. coli* data suggests that overall levels have increased. However, changes in the monitoring programme may indicate an increase in analytical values which do not necessarily reflect a real deterioration in the environment. In addition, due to the inherent variability in the environment the time frame of any comparative assessment to determine 'deterioration' would be critical.

Consultees at all levels and throughout all departments were unaware of any specific commitment to maintain a specific water quality, or shellfish Classification standard. This lack of a clear objective has left a planning vacuum.

6.8.5 Future Considerations

The current legislative position with respect to shellfish waters needs to be improved. The Water Pollution (Jersey) Law 2000 commitment to no deterioration, whilst admirable, is ambiguous. Conversely, the SWD as a legislative driver for improvement is absent in Jersey leaving a vacuum in the planning of water quality requirements to help protect shellfish waters.

On the positive side many of States of Jersey operations could be considered as examples of good or best practice relative to those practiced in the UK. It is suggested that there is urgent need for open dialogue between stakeholders to establish shellfish quality objectives (perhaps based on SWD requirements) which can be incorporated within the Liquid Waste Strategy.

With the future adoption of the WFD in 2013 incorporating the equivalent microbiological standards to the SWD there is scope to generate a new legislative framework for shellfisheries which should help provide a driver to improved shellfish quality.

Strategy Option: Establish shellfish quality objectives for Liquid Waste Strategy and Water Framework Directive.

Section 6. Strategy Option(s)

Section	Strategy Option(s)	Benefit / Importance	Output or Outcome	Cost or Funding Requirement	Timeframe for Implementation
6.1	Storm water and foul water separation such as through the adoption and retrofitting of SUDS.	**High**	Reduced waste water spill frequency allowing possible restoration of Class A status.	**Significant costs for re-sewerage**	Long term – 10 years+
6.2	Continued support for Catchment Sensitive Farming.	**Moderate**	Reduced faecal loading via watercourses.	**Moderate (Countryside Renewal Scheme extension)**	Medium Term – 5 to 10 years
6.3	More engagement with pleasure craft users to limit potential waste discharge impact.	**Low/Moderate**	Signage and information to ensure waste disposal.	**Minimal**	Short Term – less than 5 years
6.4	Establish sentinel bio-monitoring around La Collette and St. Aubins Bay.	**Moderate**	Effective tool for environmental monitoring.	**Moderate**	Short Term – less than 5 years
6.5	Water quality investigations to establish relative risks between contaminant sources.	**High**	Establish relative risks between contaminant sources.	**Moderate**	Short Term – less than 5 years
6.6	An evaluation should be carried out for the Jersey shellfish culture sector of the practical, economic and financial implications and impacts between Class A and B status of local waters.	**Low**	Costed impact of Classification changes for discussion purposes.	**Minimal**	Short Term – less than 5 years

6.7	Implement Island-based accredited impedance analytical capability.	**Moderate**	Effective tool to allow proactive sampling and analysis.	**Moderate (purchase of impedance system)**	Short Term – less than 5 years
6.8	Develop Proactive Shellfish Management System.	**High**	Improved shellfish quality and status.	**Moderate**	Medium Term – 5 to 10 years
6.9	Recommence Shellfish Liaison Group.	**High**	Better information sharing between stakeholders.	**Minimal**	Short Term – less than 5 years
6.10	Establish shellfish quality objectives for Liquid Waste Strategy and Water Framework Directive.	**High**	Clear planning requirements and standards.	**Minimal**	Short Term – less than 5 years