A Review of the Regulatory Regime for Seaweed Harvesting and Cultivation

Contributing to SIFT's engagement with the Scottish Government Review of Seaweed Harvesting and Cultivation

A Report Commissioned by:

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Date: September 2019

Contents

Glossary

ASC	Aquaculture Stewardship Council
CE	Crown Estates
EIA	Environmental Impact Assessment
EU	European Union
FAO	Food and Agriculture Organisation
FD	Fisheries Directorate
HIE	Highlands and Islands Enterprise
HLO	Harvesting Licence Options
IFREMER	Institut français de recherche pour l'exploitation de la mer
IMTA	Integrated Multi Trophic Aquaculture
MBL	Marine Biopolymers ltd
MCS	Monitoring, Control & Surveillance
MSC	Marine Stewardship Council
MS LOT	Marine Scotland Licensing Operations Team
MSY	Maximum Sustainable Yield
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SG	Scottish Government
SIFT	Sustainable Inshore Fisheries Trust
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
t	Tonnes
TAC	Total Allowable Catch

1 Introduction

1.1 Project Background

Interest in the potential for both seaweed harvesting and seaweed cultivation has been growing in Scotland in recent years, with some excitement about the potential scale of the future industry[1] to supply both high value, niche products (such as pharmaceutical raw materials or food additives), but also for large volume industrial processes such as biofuel. Regulators are seeking to keep ahead of developments within the emerging industry with proper consideration of the sustainability considerations. In 2012 the Scottish Government published a Strategic Environmental Assessment (SEA) of the Seaweed Cultivation and published a Seaweed Cultivation Policy. And in 2016 the Scottish Government published a further SEA on the effects of Wild Seaweed Harvesting.

Since then, activity and interest, on the part of academia, industry and regulators have continued. The issue of the potential sustainability, or otherwise, of large-scale seaweed harvest came to public prominence with the publication of a scoping report, on behalf of Marine Biopolymers Ltd, ahead of a Marine Licence application for mechanical harvest of kelp (*Laminaria hyperborea*). Shortly afterwards, in November 2018 during parliamentary scrutiny of the Scottish Crown Estate Act 2019, an amendment was included to restrict the removal of wild kelp for commercial use, including the method proposed by Marine Biopolymers ltd (MBL).

During the passage of the Scottish Crown Estate Act through parliament, Roseanna Cunningham, Cabinet Secretary for the Environment, Climate Change and Land Reform, announced the Government's intention to hold review of regulation or policy for wild seaweed harvesting and cultivation. This would focus on improving understanding of the scale and location of kelp[2] resources; the broader marine ecosystems which exist within and around them; and the research needs to ensure we are better informed of the environmental impacts of harvesting activities. This review process is on-going and it is intended that this paper should complement some of the scope of the review, enabling effective engagement with that review.

1.2 Report Structure

This paper was commissioned by the Sustainable Inshore Fisheries Trust (SIFT) alongside a parallel paper which focuses more on the ecological role of seaweed and the potential ecological impacts of differing harvesting and cultivating approaches. No such issues are therefore covered in this paper. There are many papers on the subject of seaweed cultivation and harvesting, most of which provide a useful summary of the industries historical context, production statistics, seaweed uses or growth projections. No attempt has been made to provide thorough review of any of these issues. Instead, this paper seeks to keep the focus on issues surrounding management practices, frameworks and legislative structures for both wild harvest and cultivation – both in current and future contexts.

The structure of the report is shaped by the outline scope of the Scottish Government Seaweed Review[3], focusing on those aspects relating to management and regulation. It begins by describing

[1] https://www.sams.ac.uk/facilities/seaweed-farms/

[2] At the first meeting of the Review steering group with was agreed that the scope should be extended to include all seaweed. https://www2.gov.scot/Resource/0054/00547666.pdf

[3] https://www2.gov.scot/Resource/0054/00547667.pdf

the existing regulatory regime for both cultivation and harvest and providing some review of that structure. It then draws on examples from other countries, to inform discussion of considerations for the future regulatory structure requirements for seaweed harvesting and cultivation in Scotland.

1.3 Constraints

This is a relatively rapid piece of consultancy work, designed to inform SIFT engagement with the Scottish Government's Seaweed Review process. No primary research was undertaken and although an appropriate range of key stakeholders were engaged with and a wide range or relevant legislation, policy statements and references were reviewed, it cannot be guaranteed that all aspects have been fully described. Although the level of review undertaken was sufficient to give broad oversight and some critical analysis, there may be unforeseen additional issues that would have become apparent during a more comprehensive exercise. As such, nothing in this report should be regarded as the definitive description. The opinions expressed in the report are those of the author and do not necessarily represent the view or opinions of SIFT.

2 The Existing Regulatory Regime in Scotland

2.1 Seaweed Harvesting

2.1.1 Crown Estates

2.1.1.1 Foreshore Harvesting

Hand harvesting of small quantities of seaweed for personal use does not require a licence nor does the collection of reasonable quantities of beach-cast seaweed for use by crofters[4]. However, harvesting of seaweed for any form of monetary or other reward from Crown foreshore or seabed does require a Crown Estate Licence. A licence would typically be granted after consultation with Scottish Natural Heritage (SNH). It is likely that SNH maybe comfortable with proposals which take a "small" amount of the of the available biomass. However, "small" is not defined here and will vary according to the species and the size of the area.

There is no explicit requirement for any assessment of resource abundance (i.e. a stock assessment), but as proposed harvest volumes increased, an assessment may be required. The requirement or otherwise for a stock assessment is likely to be based on expert opinion and perceptions of likely impact rather than empirical evidence or clearly defined thresholds. It is therefore likely that removal of 5% of the perceived biomass maybe acceptable, whereas removal of an estimated 20% would require much greater empirical evidence.

The licence does require that the quantity and location of harvesting must be recorded. There is also a charge for the licence, which is based on an estimate of business revenue, with a flat rate fee and an additional charge based on tonnage.

Larger scale proposals (> 90t[5] wet weight p/a) for foreshore and near-shore harvesting of seaweed that is not subject to statutory licensing[6] will be subject to the Crown Estates Harvest Licence Options (HLO) process[7]. This is a fuller application and requires detailed geographical co-ordinates, details of the species and proposed harvest volumes, provisional harvesting and monitoring strategies and a viable business plan. This secures the area for the grantee for a period of 3 years to enable stock assessments and associated sustainable harvesting and monitoring strategies to be developed. These must be submitted within 2 years in order to secure the harvesting licence.

Stock: The use of the word 'stock' has a reasonably clearly defined meaning in fisheries science, implying some degree of discreetness of a largely self-sustaining population. The term stock is also used in seaweed literature, but the definition seems less clear. When referring to the sustainability of harvesting a certain percentage of the 'stock' biomass, the licence application boundary, appears to serve as a proxy for the biological stock boundary.

[4] This right is enshrined in The Crofters (Scotland) Act 1993 (as amended)

[5] This tonnage threshold is not fixed and depends also upon the spatial scale of operation.

[6] See section 2.1.2 for the definition of the where statutory licencing applies.

[7] https://www.crownestatescotland.com/bundles/app/downloads/5ccb13d8a72fd_Foreshore%20Seaweed%20Harvesting%20Options.pdf

2.1.1.2 Vessel-based harvesting

Most existing licences in Scotland are for the foreshore and perhaps slightly beyond, but not requiring any vessel for harvest. An application for vessel-based harvesting would be likely to require a licence from Marine Scotland (see 2.1.2 for a description of this process). In this instance, the Crown Estate licence would only be granted subject to consent having been granted by Marine Scotland. Because the Marine Scotland licensing (and statutory consultation process) focusses more on issues of sustainability, the Crown Estate would focus less on questions of sustainability (compared with an application which was not subject to a Marine Licence), but would still retain a focus on ensuring that the proposed licensee has an appropriate business model. However, they would retain the power to place conditions on licences to limit harvest, or require data recording or even vessel monitoring systems (VMS) or remote electronic monitoring (i.e. on-board CCTV cameras).

Extract from the Scottish Crown Estate Act 2019.

15 Restriction on removal of wild kelp from seabed

(1) The manager of a Scottish Crown Estate asset must not grant a right to remove wild kelp from the seabed (that is, the bed and subsoil of the sea within the Scottish marine area) if either subsection (1A) or (1B) applies. 30

(1A) This subsection applies if—

(a) removal of the kelp would inhibit the regrowth of the individual plant, and

(b) the kelp removed is intended for commercial use.

(1B) This subsection applies if—

(a) removal of the wild kelp is a licensable marine activity, and

(b) the Scottish Ministers have not granted a marine licence for that removal.

The Scottish Crown Estate Act 2019 now prevents the licencing of any form of harvesting which would inhibit the regrowth of the individual plants. This therefore effectively prohibits vessel-based harvesting which removes the holdfast from the Crown seabed, even if this same activity is not ineligible for a Marine licence, issued under the Marine (Scotland) Act 2010.

2.1.1.3 Exclusivity of access

The Crown Estate licence does not give exclusivity of access to an area. So, if other applicants could demonstrate that there was sufficient resource, they too would likely be granted a licence. Because the majority of existing licence holders are operating at levels well below a nominal (but non-empirically demonstrated) MSY figure, there remains opportunity for further applicants to be granted rights in the same area.

However, if a licenced operator was operating up to a demonstrated "maximum sustainable yield", within licence conditions, then no new licence would be granted within the same area. There is no proposed mechanism to adjust the size of the initially licenced allocations to allow new entrants to take a share of the sustainable harvest. So early entrant, large operators may achieve effective-exclusivity of access, to potentially large areas on a first-come basis. Licences would typically be renewed if conditions had been complied with, so a well-funded early-adopter could retain effectively-exclusive harvest rights in an area as long as required.

This could close the door to small scale artisanal harvesters seeking to engage in the industry once a market for the raw material has been established.

2.1.1.4 Other landlords

It is important to recognise that some large areas of foreshore in Scotland are not owned by the Crown Estates. In these areas the Crown Estate has no role in licencing harvesting. For example, in Uist, large quantities of seaweeds are harvested from privately owned foreshore. Although no suggestion is made that this practice is currently anything other than sustainable, it is interesting to note that the private landlord has no obligation to consult with SNH prior to allowing harvest to proceed. The only safeguard to ensure a sustainable harvest is the approach, attitude and diligence of both the landlord and the permitted harvester. Furthermore, there is no requirement to submit data on the quantity of biomass removed, so a wider exercise seeking to model the impact of overall levels of biomass removal over a wide area may lack data from biomass removals from non-Crown seabeds and foreshore.

One exception to this occurs if harvesting is taking place on a private foreshore which is a designated Site of Special Scientific Interest (SSSI)[8]. In those circumstances SNH is the competent authority and would be consulted. However, if harvesting is taking place on a private foreshore which was a Special Protection Area (SPA)[9] or a Special Area of Conservation (SAC)[10] but not an SSSI, then the definition of Competent Authority, and the need therefore to consult with SNH is more ambiguous (SNH *pers. comms*).

2.1.2 Marine Scotland

As noted above, it is likely that commercial scale seaweed harvesting by vessel will be deemed a "licensable activity", within the definitions of Marine (Scotland) Act 2010. This is primarily due to articles 21 (6 & 7), which state that the use of vehicle, vessel, aircraft, marine structure or floating container to remove any substance or object from the seabed (including any form of dredging) within the Scottish marine area is licensable. However, there is some ambiguity about whether a vessel *mowing or cutting* the upper part of seaweed would be deemed to be removing a "substance or object from the seabed". A tighter definition, or specific policy guidance around this point may be required to make it explicit that any form of vessel-based seaweed harvesting requires a licence.

Licencing decisions are taken by the Marine Scotland Licensing Operations Team (MS LOT), in accordance with the Scottish National Marine Plan (Marine Scotland 2015)[11]. However, seaweed harvesting is not mentioned as a sector within the Scottish National Marine Plan. Consultation is required prior to MS Lot taking a licencing decision. The statutory consultees are:

- Northern Lighthouse Board (NLB)
- Maritime & Coastguard Agency (MCA)
- Scottish Natural Heritage (SNH)
- Scottish Environment Protection Agency (SEPA)
- Marine Planning Partnerships (where established).

Non-statutory consultees include, but are not limited to:

[8] SSSI is a statutory designation made by Scottish Natural Heritage under the Nature Conservation (Scotland) Act 2004.
[9] Under Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds
[10] Under the European Union Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.
[11] Once published the Scottish Regional Marine Plans from the Marine Planning Partnerships will also be a key guide to licensing decisions.

- the Royal Yachting Association (RYA),
- the Crown Estate (CE),
- Scottish Fisherman's Federation (SFF),
- Marine Scotland Science (MSS),
- Historic Scotland,
- Transport Scotland
- any relevant Harbour or Port Authority

2.1.3 Environmental Impact Assessment

Seaweed harvesting is not listed under either schedule 1[12] or schedule 2[13] of The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017 or The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017. This means that an environmental impact assessment would not typically be required for seaweed harvesting, even if it was deemed a licensable activity. In their scoping report, Marine Biopolymers note that:

> *"Wild seaweed harvesting is not an activity that is subject to the requirements of the EC Environmental Impact Assessment Directive (2011/92/EU as amended) and therefore MBL is not required to submit a formal Environmental Statement with its marine licence application. However, MBL is committed to demonstrating high standards of environmental stewardship and will therefore provide a detailed Environmental Report alongside its marine licence application".*

[12] http://www.legislation.gov.uk/ssi/2017/102/schedule/1/made
[13] http://www.legislation.gov.uk/ssi/2017/102/schedule/2/made

2.2 Seaweed Cultivation

2.2.1 Crown Estates

There is currently almost no commercial seaweed cultivation in Scotland. There is some experimental cultivation and one lease has been granted, but the site is yet to go into production. Seaweed cultivation leases differ from seaweed harvesting licences and are granted along similar lines to marine aquaculture leases, although under a different regime. This Crown Estates lease would also be granted subject to a Marine Scotland licence being granted. By contrast to a seaweed harvesting licence, this cultivation lease does give the grantee exclusivity to the resource within a defined area. A rent is charged based on an analysis of the business – i.e. production costs and market value.

Is seaweed cultivation aquaculture?

Aquaculture or "fish farming" is legally defined in the Town and Country Planning (Scotland) Act 1997 as 'the breeding, rearing or keeping of fish or shellfish (which includes any kind of crustacean or mollusc)". This was amended by the Town and Country Planning (Marine Fish Farming) (Scotland) Regulations 2013 to include sea urchin, but *not* seaweed.

2.2.2 Marine Scotland

Commercial scale seaweed cultivation will be deemed to be a "licensable activity", within the definitions of Marine (Scotland) Act 2010 due to the need to install marine farm equipment, moorings, buoys etc. A Marine Scotland licence will therefore be required and Marine Scotland provide a dedicated application form for Algal Farms[14]. This states that large projects with potential for significant impacts on the environment, local communities and other legitimate uses of the sea must submit a pre-application for public consultation and hold a consultation event. Details of what must be included within this pre-application are set out in The Marine Licensing (Pre-application Consultation) (Scotland) Regulations 2013[15].

The Marine Licence application focusses largely on the spatial and infrastructure characteristics of the proposed farms, with less focus on the species, production volumes or production techniques. Licencing decisions are taken in accordance with the Scottish National Marine Plan (Marine Scotland 2015). Seaweed cultivation is briefly mentioned within the aquaculture sector of the plan. As with licencing described above for seaweed harvesting, consultation is required prior to MS Lot taking a licencing decision, with the same consultees listed above. Licences for algal forms are typically issued for 6 years.

2.2.3 Role of the Local Authority

Unlike other forms of aquaculture, seaweed cultivation is not included in the Town & Country Planning (Scotland) Act 1997. This therefore means that, unlike for other forms of aquaculture, planning permission is not required (Nimmo *et al* 2016). It is also notable that the local authority is not a statutory consultee under in the Marine licencing process.

[14] https://www2.gov.scot/Resource/0049/00498667.pdf
[15] http://www.legislation.gov.uk/ssi/2013/286/made

2.2.4 Environmental Impact Assessment

As with seaweed harvesting, an EIA is not an automatic requirement for seaweed cultivation as seaweed cultivation is not listed under either schedule 1 or schedule 2 of The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2017 or The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017. This means that an environmental impact assessment would not be required for seaweed cultivation. Although 'aquaculture' is listed in Schedule 2, this goes on to specify "fish farming", so seaweed cultivation is not included.

Extract from the Seaweed Cultivation Policy Statement (Marine Scotland 2017)

Policy 1: in principle, the SG is supportive of small-medium farm seaweed cultivation, subject to regulatory consideration; the General Policies set out in Chapter 4 of Scotland's' National Marine Plan; and any other relevant policies within that Plan. Applications for such seaweed farms should demonstrate that mitigation measures have been considered to prevent adverse environmental effects, and set out how these will be delivered.

Policy 2: only species native to the area where seaweed cultivation will take place should be cultivated, to minimise the risk from non-native species

Policy 3: where seaweed is grown for human consumption, cultivators should site farms away from sewage outfalls and other potential sources of pollution

Policy 4: equipment used in seaweed cultivation should be fit-for-purpose to withstand damage from adverse weather conditions

Policy 5: other marine users and activities should be considered in the siting of farms

Policy 6: small-medium size farming is unlikely to be spatially limited, and may be located anywhere in Scotland, subject to agreement and appropriate local conditions

Policy 7: the SG is supportive of IMTA

2.2.5 Non-native species

There is already regulation in place to prevent the growing of non-native seaweeds. As noted in the Marine Scotland Seaweed Cultivation Policy Statement "Amendments to the Wildlife and Countryside Act 1981 under the Wildlife and Natural Environment (Scotland) Act 2011 make it an offence for a person to plant or cause any plant species to grow out with its native range. This includes species of seaweed which can grow in the marine environment".

3 Review of the Current Regulatory Regime

When considering the current regulatory structure of for both seaweed harvesting and seaweed cultivation in Scotland, there are some opportunities which arise and may be usefully considered during the Scottish Government Review.

3.1 Ownership of the Resource

A fundamental question is "who owns the resource"? At the early stage of a developing industry this question may seem less important, but as the industry develops and as the value of "entitlements" increase, then the question is likely to grow in importance. In the case of cultivation, this question is likely to be clearly answered, because a licence is granted for a location, for a period of time, and during that time the cultivated seaweed is the property of the producer. This offers protection for the producer and safeguards the investment in equipment and apparatus.

The Icelandic Fisheries Management Act 2006

Article 1

The exploitable marine stocks of the Icelandic fishing banks are the common property of the Icelandic nation. The objective of this Act is to promote their conservation and efficient utilisation, thereby ensuring stable employment and settlement throughout Iceland. The allocation of harvest rights provided for by this Act neither endows individual parties with the right of ownership nor irrevocable control over harvest rights.

For wild harvest seaweed the answer to the question is less clear. Does a licence to harvest constitute "ownership" of that resource? This must be clearly established, to avoid unintended consequences. In UK fisheries there has been a gradual evolution from fisheries being seen as a common resource, to becoming a tradable commodity. This has been described as the privatisation of fisheries (Carothers & Chambers 2012). Licences have become transferable and quota trade has become liberalised and less linked to track record. As a result, ownership of fish quotas and therefore vessels inevitably concentrate in fewer and fewer hands (Although 79% of UK vessels are under 10 m in length, the remaining 21% account for 89% of the UK catch by value (Appleby *et al* 2018).

At the same time, the policy options for the government or regulator become more limited meaning that it is harder to use the once common resource for socially valuable purposes like creating opportunities for new entrants, or supporting a diverse rural economy. Where such policy interventions are attempted, they may be open to (successful) legal challenge (e.g. United Kingdom Association of Fish Producer Organisations (UKAFPO) v Secretary of State for the Environment, Food and Rural Affairs 2013)[16]. Article 1 of the Icelandic Fisheries Management Act (see box), neatly summarises how such a situation has been avoided in Iceland and also highlights how this enables the government to achieve its objectives, not only to the environment, but also to the rural economy. If, in the future, seaweed becomes a valuable resource, careful consideration should be given to how ownership of the resource is addressed.

3.1.1 Can access be charged and how are costs of science and monitoring met?

Closely connected to the question of ownership is the question of responsibility for seaweed science as well as future monitoring, control and surveillance (MCS). At present the Crown Estate

[16] https://www.judiciary.uk/wp-content/uploads/JCO/Documents/Judgments/uk-assoc-fish-producer-orgs-10072013.pdf

charge for both a harvesting licence and a cultivation lease, based on an estimate of market value. However, this charge is not intended to cover the costs of either science or enforcement.

Although, in the past some estimates of seaweed biomass abundance have been paid for by centrally funded projects, it is clear that it will largely be the responsibility of the licence applicant to undertake the assessment work to demonstrate that the proposed level of harvest is sustainable. For large scale licence applications this is potentially expensive and complex undertaking, which may be justified if the economics of future operation are proven. The lack of centrally funded stock abundance estimates disincentives licence applications from applicants without the resources to undertake stock abundance estimates. It is notable that in other countries with seaweed harvesting industries (including Norway and France) the state research agencies do continue to play an active role in seaweed science. It is also notable that in the UK fish stock science is (in the most part) centrally funded. However, if more centrally funded research was to be provided, then the licence charge may need to increase to cover this.

3.2 Monitoring

Monitoring is a crucial and often overlooked aspect of sustainable development. Without effective monitoring of appropriate indicators, it is not possible to determine if the policy goals are being met. It has been noted at the first meeting of the Scottish Government Seaweed Review steering group that at present there is no database of information on what seaweed harvesting activity is currently occurring in Scotland, which means that considerations of cumulative impact or trends over time cannot be easily assessed[17]. It is also notable that although the mechanism exists to require those with a Crown Estates licence to submit data in harvest quantities, it is not clear to what extent this data has been collated and no such mechanism exists to derive data from privately owned foreshore. At this early stage of the industry this data is essential to help inform understanding of future patterns, both of exploitation and abundance.

3.2.1 Resource abundance

In Scotland, an often-cited survey was undertaken by the Scottish Seaweed Research Association in 1947 (Walker 1947 a & b). The same author did additional studies in the 1950s including investigation of growth rates. Surveys since then have been more sporadic or focussed on particular areas (e.g. Bryan 1994). A more recent survey was undertaken in 2010, commissioned by Scottish Enterprise and Highlands and Islands Enterprise (HIE). Although this focussed on the rockweed (*Ascophyllum nodosum*) the methodology, based around survey and habitat modelling, was seen as applicable to other seaweed species (Burrows *et al* 2010). A similar modelling approach was extended to additional species to inform a more recent study, also commissioned by HIE (Burrows *et al* 2018).

In Ireland trials have been used with Single Beam Echosounder (SBES) with modified signal-processing software to determine the spatial distribution of kelp compared to biomass estimates determined by SCUBA diver ground truthing (Bright *et al* 2011). This showed positive results for the remote sensing technique, although it was unable to distinguish between kelp species.

There therefore remains considerable opportunity to improve techniques for estimating biomass abundance. An associated question which must also be addressed is the frequency of stock assessment. It is notable that in some countries an annual stock assessment is required to support

[17] https://www2.gov.scot/Resource/0054/00547666.pdf

the on-going licence to harvest. Currently, the frequency of stock monitoring required under a licence is not specified.

3.2.2 Industry productivity

Monitoring and recording data on the harvest volumes of species is crucial to enable any form of industry analysis and help shape policy. Careful consideration should be given, prior to major expansion of the industry, to the fields of data that are required. Species, tonnage and area are perhaps the obvious fields, but data to enable analysis of Catch per Unit Effort (CPUE) can enable the efficiency of different harvesting techniques to be assessed and may provide a useful data field to inform understanding of changing yields. As seaweed stock science develops further reliable production time series data is likely to prove useful. Robust and reliable data is likely to be the key to analysing and modelling the industry as it grows.

3.2.3 Environmental impacts

All seaweed extraction, whether from wild harvest, or cultivation will create an environmental impact. Regardless of whether these impacts result in positive change (as some have argued) or negative change (as other have argued), it is crucial that regulators put in place a routine system of environmental monitoring so the impacts of earlier policy decisions can be quantified.

There is also a need to understand how the seaweed cultivation may impact upon fisheries yields. As seaweed growth requires nutrients and light which will reduce natural phytoplankton production. By harvesting the cultivated seaweed, a fraction of the ecosystem's net primary production is removed, thus reducing the ecosystem carrying capacity, which in turn may impact ecosystem productivity and ultimately, fish stocks (Préat *et al* 2018).

3.3 Harvest Strategy

It is important that a notional maximum sustainable yield should be the target for exploitation, however the estimation of this should not be over-simplified. It is tempting to accept that harvesting say 25% of the available biomass within an area and rotating harvest areas say every 4 years is probably sustainable (even though some countries use a lower default percentage and a longer rotation period and it is likely that figures appropriate for one species, in one area at one time would not be applicable to another species, area or time). But without evidence and on-going monitoring this approach is a high-risk strategy and should not be conflated with an empirically modelled maximum sustainable yield.

This approach also suffers from being static. There is no scope to reduce exploitation rates as yields reduce. For example, if the available biomass abundance significantly reduces due to external factors, such as climate change, will the reduction be identified and will the harvest strategy be responsive in a timely manner? Or will the same default percentage be applied in spite of the worsening environmental status. As well as defining the maximum sustainable yield, the harvest strategy should therefore also identify key refence points, such as the limit available biomass below which all harvest operations will cease. Ideally, these reference points would be set based on an understanding of the ecosystem services provided by the harvested resource. It should therefore be a licence requirement for commercial seaweed harvests that an adaptive harvest strategy is in place, not just a static harvest rate based around a non-empirically demonstrated MSY figure.

In order to have sustainable management of seaweed harvest and culture there must also be reliable understanding of the underlying biological mechanisms controlling macroalgal life cycles, such as the production of germ cells to the growth and fertility rates. It has been argued that further basic research on macroalgal developmental biology is still required to fill the gaps in fundamental knowledge of macroalgal developmental mechanisms to inform truly sustainable management (Charrier *et al* 2017). This is essential to inform aspects of the harvest strategy such as limit biomass, MSY and fallow periods as well as determining the effects of different harvest mechanisms.

4 Alternative approaches to sustainable regulation

Drawing from examples from other jurisdictions or best practice from other sectors

4.1 International Sustainability Schemes

In 2017 the Marine Stewardship Council (MSC) and the Aquaculture Stewardship Council (ASC)[18] released a joint seaweed standard, covering both wild harvest and cultivation. The standard is guided by five core principles:

- sustainable populations;
- minimising environmental impacts;
- effective management;
- social responsibility; and
- community relations and interactions.

The standard does not allow for the certification of alien or introduced species, unless the introduction occurred over 20 years previously, or the is undertaken in a completely closed land-based unit. Harvesting or farming activities which use mutagenic, carcinogenic or teratogenic pesticides, or any other chemicals that persist as toxins in the marine environment or on the farm or farmed seaweeds, are not eligible for certification.

The Principles and Criteria of the MSC / ASC joint seaweed Standard

Principle 1 Sustainable wild populations	Principle 2 Environmental impacts	Principle 3 Effective management	Principle 4 Social responsibility	Principle 5 Community relations and interaction
PI 1.1 Stock status	PI 2.1 Habitat	PI 3.1 Legal and/or customary framework	PI 4.1 Child labour	PI 5.1 Community impacts
PI 1.2 Harvest strategy	PI 2.2 Ecosystem structure and function	PI 3.2 Decision-making processes	PI 4.2 Forced, bonded or cumpulsory labour	PI 5.2 Conflict resolution
PI 1.3 Genetic impact on wild stock	PI 2.3 ETP species	PI 3.3 Compliance and enforcement	PI 4.3 Discrimination	PI 5.3 Rights of indigenous groups
	PI 2.4 Other species		PI 4.4 Health, safety and insurance	PI 5.4 Visability, positioning and orientation of farms or water-based structures
	PI 2.5 Waste management and pollution control		PI 4.5 Fair and decent wages	PI 5.5 Identification and recovery of substantial gear
	PI 2.6 Pest(s) and disease(s) and management		PI 4.6 Freedom of association and collective bargaining	PI 5.6 Noise, light and odour
	PI 2.7 Energy efficiency		PI 4.7 Disciplinary practices	PI 5.7 Decommissioning of abandoned production units
	PI 2.8 Translocations		PI 4.8 Working hours	
	PI 2.9 Introduction of alien species		PI 4.9 Environmental and social training	

Source: https://www.asc-aqua.org/wp-content/uploads/2017/11/Get-Certified-Guide-Seaweed.pdf

Under Principle 1 the standard requires that the wild stock is exploited at MSY and defines this as "The highest theoretical equilibrium yield that can be continuously taken (on average) from a stock under existing (average) environmental conditions without affecting significantly the reproduction process". It also requires that there is a harvest strategy in place, which is *responsive* to the state of the stock, and works to ensure the stock remains at a level consistent with long term MSY. Interestingly, these performance indicators must also be applied for cultivated seaweed which is reliant upon a wild population for seeding.

Principle 2 addresses the wider impacts of either harvesting or cultivation, including impacts on habitats, ecosystem functionality and protected species. As well as considering issues such as waste management. Principle 3 examines the legal structures and compliance with laws and regulations. Principle 4 differs from the default structure of the Marine Stewardship Council standard for fisheries by introducing an audit of social responsibility.

The final Principle (Principle 5) examines Community Relations and interaction. This is a particularly important consideration given the potentially large spatial scales of seaweed

[18] "The ASC and MSC certification programs are globally recognised as the world's most credible, science-based standards for sustainable and responsible seafood. All MSC and ASC standards have been developed following the ISEAL Code of Good Practice for Setting Social and Environmental Standards and FAO Guidelines". https://www.msc.org/media-centre/press-releases/asc-and-msc-release-joint-seaweed-standard

harvesting or cultivation. This brings in consideration of issues such as noise, light and odour pollution and considers issues such as visibility and positioning of water-based structures. Finally, the standard also explicitly requires that issues such as the decommissioning of water-based structures receives proper consideration.

Whilst this report does not go further into the detail of the seaweed standard, it is clear that both harvest strategy and planning considerations are key criteria. For both of these, there appears to be scope for further improvement and additional rigour within the existing Scottish seaweed licencing system. As the Scottish Government moves forward with its review of seaweed regulation, it would seem reasonable that it should target a future regime capable of delivering an industry which is well-placed to be accredited against the leading sustainability standard for seaweed. The MSC and the ASC joint seaweed standard should therefore be a useful point of reference for the review.

4.2 Other countries

It is also useful to draw on examples from other countries, to inform the future management of seaweed harvesting and cultivation in Scotland. Some countries have been successful in developing sustainable seaweed harvesting and examples of this are highlighted below. However, the are other examples, such as Peru and Brazil where a rapid growth in the seaweed industry has led to considerable challenges and significant market-driven over-exploitation.

4.2.1 Norway

4.2.1.1 Wild Harvest

Norway has a well-established management regime for the sustainable exploitation of seaweed based on sound knowledge and cross-sectorial spatial plans (Rebours *et al* 2014). Seaweed harvesting and management is the responsibility of the seaweed processing industry (owned by international capital), with one company for *Ascophyllum nodosum* and one company for *Laminaria hyperborea*, each with exclusive harvesting rights (Frangoudes 2011). The *A. nodosum* is harvested by vessels owned by the company (although many of the fishers themselves are self-employed). The annual permitted tonnage is set by the processing company. Access to the inter-tidal zone requires negotiation and payment to private land-owners but even within this privately-owned area national regulations apply.

L. hyperborea is also harvested by vessel, some of which are company-owned and some of which are privately owned. All are registered fishing boats. Although the total catch level is set by the company, there is a requirement to submit a harvest plan to the Fisheries Directorate (FD) prior to harvesting. Logbooks showing catch composition, quantity and origin are inspected by the FD and a yearly report is submitted to the FD. Harvesting is undertaken in zones, which are rotated. Again, this rotation is managed by the company. Initially this was a 4-year rotation, but this has since increased to 5 years. Fishers harvest 10 to 15% of the available biomass each year. The Norwegian state research institute is directly involved in the scientific aspects of the Norwegian seaweed harvest. The evaluation of kelp stock is assessed by Institute of Marine Research (IMR), as is the monitoring of impacts of trawl activity (financed by the FD) (Frangoudes 2011).

Although the Norwegian seaweed harvesting model is often referred to in a positive light in much of the academic literature, it is not immune from regional conflicts between seaweed trawling industry and other coastal resource users (such as fishermen and marine conservation groups) (Stévant *et al* 2017).

4.2.1.2 Cultivation

Seaweed cultivation is also at an early stage in Norway with most taking place on a research or pilot scale. Licensing differs for harvesting and cultivation. An interim licencing scheme has been introduced for seaweed cultivation with licences granted by the Ministry of Trade, Industry and Fisheries, according to aquaculture legislation (Stévant *et al* 2017).

4.2.2 France

France has a long history of management of seaweed harvests. The Inter-professional committee of marine seaweeds (CIAM) was established in 1961 and brought processors and harvesters together. Initially this examined ways to increase the harvest but by the late 1970s the focus had shifted to the need for proper regulation of harvesting. Since the mid 1980s licensing and logbooks have been mandatory. Further restrictions on seasonality and quota were introduced shortly thereafter. Since then management of seaweed resources has fallen to fishermen's organisations alongside other fisheries resources. The quota system has evolved further into individual quotas and with scientific input and monitoring from the state marine research institute (IFREMER) (Frangoudes 2011).

4.2.3 Chile

Seaweeds are seen as benthic resources along with fish species and are managed under Territorial User Rights in Fisheries (TURF). Those gathering seaweeds are therefore regarded as fishers (Frangoudes 2011). Because of the recognition of importance of seaweeds to coastal benthic fisheries such as sea urchins and molluscs, management has sought to regulate seaweed harvesting to protect not only the target species, but also the associated biodiversity, recognising the functional role within the ecosystem played by the seaweed. The approach to management uses some degree of co-management, between state and industry and sets morphological constraints, quotas by fishing area, rotations and experimental areas (Vásquez *et al* 2012, Rebours *et al* 2014). Annual management plans for seaweeds must be based on annual stock evaluation (Frangoudes 2011).

4.2.4 1.1.1 South Africa

In South Africa the harvesting of seaweed resources is managed in terms of both a Total Applied Effort (TAE) and a Total Allowable Catch (TAC) which limits the harvest within concession areas, with a Maximum Sustainable Yields (MSY) equate to 10% of the estimated *accessible* biomass, a value that was estimated to equal the annual mortality rate (Amosu *et al* 2013). South Africa has also integrated seaweed cultivation into abalone culture, which not only produces a food resource for the abalone culture but also serves as a biofilter. The seaweed growth is boosted by the increased nitrogen content of the abalone effluent (Amosu *et al* 2013).

4.2.5 Peru

The arrival of Chinese owned companies created a rapid increase in market demand for seaweeds and a 'short-term and uncontrolled intensification of harvesting' which led to over-exploitation. By 2014 Peru did not have appropriate regulation for harvesting seaweed (Rebours *et al* 2014).

5 Discussion

Harvesting of wild seaweed and cultivation of seaweed are fundamentally different industries. Although the end product may have a similar (or even identical) market, the potential impacts of production and issues for consideration for regulation differ sufficiently to warrant a separate regulatory regime. Harvesting is more akin to fishing, where a licence is issued to harvest a portion of a common resource. Whereas in cultivation a producer invests in a leased site to produce material for their exclusive use. In going forward, clear distinction should be made between harvesting and cultivation of seaweed.

5.1 Wild Harvest

5.1.1 A strategic approach to ensure sustainable level of harvest

The mechanism by which the sustainable threshold for harvest is determined should be further refined. Default values for the percentage of biomass that can be removed or the frequency of harvesting areas and fallow periods cannot be relied upon. These values will differ according to area, species and other environmental factors, such as temperature or nutrient levels. Reliance on such static default figures fails to recognise the natural variation within the ecosystem, or how the act of harvesting may affect the local productivity. It is an approach that risks over-exploitation.

Instead, harvest strategies must be more adaptive. An effective strategy should clearly state target and limit biomass levels, informed by empirical evidence for the species involved. An effective strategy should also detail how harvest rate will be adjusted in response to changes identified in on-going monitoring. The setting of harvest strategy parameters should be informed by science, but also shaped in an integrated and participatory manner and with a long-term perspective. Ecosystem based management plans are key to this (Rebours *et al* 2014), which recognise not only the inherent ability of the species to reproduce for maximum yield, but also the ecosystem function played by that species. Given the critical role that seaweeds play in marine ecosystems it may be that the target harvest level should be set at a more precautionary level than MSY.

Harvest strategies should also be subject to review, to ensure that they are achieving the stated objectives and if necessary, adjusted. This form of adaptive and strategic management should help to ensure that the level of harvest is not only initially sustainable, but continues to be sustainable as the environment changes and the industry develops.

As popularity of seaweed grows, demand may grow for previously unharvested species, with novel applications, therefore the management framework must be robust to changes in the character of the industry (Mac Monagail *et al* 2017). A regulatory regime which relies upon a static percentage for biomass removal and harvesting frequency will lack the strategic considerations to ensure on-going sustainability as the industry develops.

5.1.2 An appropriate degree of precaution

The science of empirical stock assessment of seaweeds is relatively young. Much of this focuses on making a static assessment of existing biomass. Modelling of future biomass levels under differing harvesting scenarios has not been developed to the extent is has in fisheries. Therefore, the consequences of seaweed harvesting, both the target stock and the wider ecosystem are, to some extent, unknown. For this reason, an appropriate level of precaution is required. This already exists, in so far as the Crown Estates and SNH are likely to demand greater empirical evidence

before licencing 'larger' scale harvesting, which is perceived to be close to a nominal MSY. However, the threshold at which an application is deemed 'larger' scale and thus requiring greater empirical evidence is not defined. This should be more tightly defined. Given the uncertainty in stock science, large scale industrialised harvesting should only be introduced as a phased progression, with interim / pilot scale licencing informed and guided by monitoring (Angus 2017).

5.1.3 Who should harvest seaweed?

The UK fishing industry provides a useful and relevant example to guide the development of the seaweed harvesting industry. The characteristics of the market, historical trends of exploitation and the nature of the licencing regime have all shaped the fishing industry that we have today. In simple terms, this has led to the highest value pelagic fisheries (e.g. herring and mackerel) being harvested by a small number of very large and very profitable vessels and the majority of catch entitlement / allocation for many demersal species such as cod and haddock held by larger trawl vessels (Appleby *et al* 2018). By contrast, the inshore under 10m fleet which account or the majority of employment mostly access non-quota species, or limited access to some quota species from a 'pool'.

When considering a new and emerging industry it is important that government policy helps to intentionally shape the composition of the future industry. It is entirely possible to have an ecologically sustainable and well managed seaweed harvesting industry made up of many, many small scale, local harvesters. Just as it is entirely possible to have an ecologically sustainable and well managed seaweed harvesting industry made up of a single large, perhaps even multi-national company. Government policy should seek to shape which of these outcomes is preferable or more likely, what balance should exist between these two outcomes. This will influence the long-term social and economic sustainability of the seaweed industry and will also influence the degree of support from a wide spectrum of stakeholders for the emerging industry.

The existing licencing system appears to enable large, well-funded entrants into the market obtaining *de facto* exclusivity by empirically demonstrating MSY and applying for a licence to harvest up to that point. This would effectively prevent smaller scale entrants joining the industry at a later stage. However, if the objective of policy is to support a diverse rural economy, or provide a diversification opportunity for inshore fishermen, then further safeguards may be required within the licensing regime, to safeguard some resource or harvesting opportunities for these purposes (just as the 'pool' exists for quota fish species) or to allow reallocation at a later stage.

To inform this, there is a need for improved understanding of the economics of harvesting. Much will depend on the market and processing is likely to require sufficient scale of harvest to be viable. But is it economically viable for the requisite harvest volume to be provided by many small harvesters? If so, there is the opportunity to shape an industry in which opportunities for small scale local entrants remain open. This is very much the model in France and even in Norway, where the harvest rights are held by just 2 companies, many privately-owned vessels contribute to the harvest.

Seaweed harvesting has been used to reverse declines in rural depopulation (Rebours *et al* 2014). Perhaps it may yet be a much-needed opportunity for Scottish rural economy.

5.2 Cultivation

Seaweed cultivation is often regarded by policy-makers as a potentially positive form of mariculture with the potential to absorb excess nutrients and so contribute to marine ecosystem objectives. However, a number of papers note that this positive impact has not been demonstrated and is likely to be counter-balanced by some potentially negative impacts. A recent paper reviewing the Canadian experience of seaweed cultivation noted: "cultivating seaweeds has harmful effects on marine biodiversity in parallel with how terrestrial agriculture has harmful effects on land-dwelling biodiversity and the best that can be done is to minimise harm to natural habitats and organisms they support" (Small 2018). Others have noted that even where there is a positive ecosystem benefit, cultural services are likely negatively affected (Hasselström *et al* 2018)

When taking seaweed production from an experimental cultivation scale to a commercial production scale a thorough assessment of the risks as well as the potential benefits of seaweed aquaculture must be undertaken. The regulatory framework should be tailored to the characteristics of the emerging industry, which anticipates and mitigates for potential risks such as genetic interactions between cultivated and wild crops, impacts of seaweed cultivation on surrounding ecosystems, epiphytes and diseases (Stévant *et al* 2017).

Cultivated seaweeds are already undergoing domestication to produce more efficient cultivars (Small 2018). It is likely that there will be demand to develop crops which are resistant to fouling, or faster growing, or produce a higher yield of the end product of processing. There are well-known risks associated with the introduction of non-native species for cultivation and their intentional use is already rightly prevented by regulation. But there is also a potential threat from the use of selected varieties of native species or translocation of native species from one region to another which might enable genetic material from cultivated crops, which differs from local populations to be introduced. There is therefore a need for improved understanding of genetic patterns and the degree of isolation between populations of native seaweed. It would be precautionary to only use local ecotypes for local cultivation (Stévant *et al* 2017).

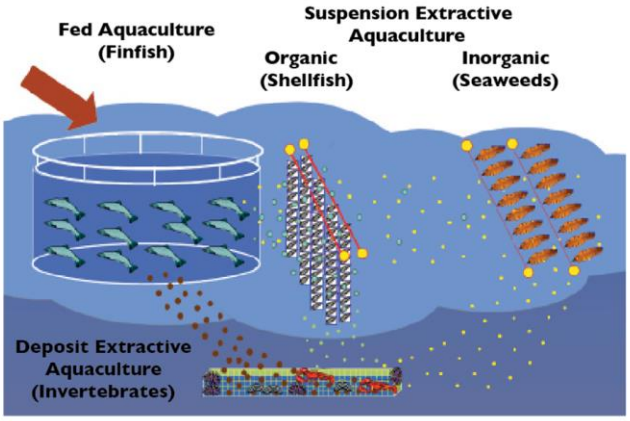
5.2.1 Consenting

A number of studies have highlighted that the consenting requirements for seaweed cultivation differ from those for other forms of aquaculture (Nimmo *et al* 2017, ABPmer and Poseidon Aquatic Resource Management Ltd 2019). Given the potential risks and potential for conflict with over legitimate users of the sea it is important that seaweed cultivation is subject to the same regulatory checks as other forms of aquaculture. Some of the uses of cultivated seaweed which are being discussed at a policy level (such as for biofuels) are likely to require very, very large areas of production. Cultivation on such a scale has the potential for considerable impact, both on the local ecosystem and on other legitimate users of the sea. It therefore seems to be essential that the consenting process is brought more into line with the consenting process from fin-fish aquaculture and in particular that the issues relating to planning are properly addressed.

5.2.2 Integrated Multi Trophic Aquaculture

There has been a lot of academic interest in Integrated Multi Trophic Aquaculture (IMTA), over many years (e.g. Chopin et al 2004, Chopin 2013), but to date there has been relatively little adoption by the finfish aquaculture industry, in part due to economic constraints and lack of perceived market benefits (Kinney 2017). There are currently no commercial-scale integrated aquaculture systems in operation in Scotland, although there have been some experimental / pilot schemes (e.g. Loch Duart Salmon). Analysis by the Scottish Aquacuture Research Forum identified a number of "game stopping' constraints" to its widespread adoption (Hughes & Kelly 2011).

Figure x: Conceptual diagram of an Integrated Multi-Trophic Aquaculture (IMTA)



Source: Chopin 2013.

There are also potential environmental risks of IMTA which must not be overlooked as the regulatory regime moves to encourage its adoption (Stévant *et al* 2017). IMTA should not therefore be seen as a panacea. Whilst it may offer some potential, the reasons why it has not been more widely adopted until now in Scotland should be explored. One possible barrier (although this is not thought to be the biggest obstacle) is the fact that the current licensing regime only allows for single species sites. Any review of seaweed cultivation regulation should recommend that this is changed to allow IMTA.

6 Conclusion

It is likely that it is possible to achieve a seaweed harvesting industry in Scotland which is ecologically sustainable. However, this will only be achieved if the regulatory framework is sufficiently robust to ensure the controlled development of the industry as it matures. The regulatory framework should therefore not only have a clear requirement for empirical evidence but also a strategic approach, informed by appropriate monitoring which can adjust patterns of exploitation according to industry developments and changes in the environment. The setting of harvest levels should focus not solely on the ability of the targeted resource to recover and re-grow, but should also recognise the ecological function of the resource and demonstrate that this functionality is not adversely impacted by the proposed harvest level. This approach to informed and adaptive strategic management of harvest is equally applicable to large or small scale harvesting and regardless of the species or location. Whilst it is reasonable for smaller scale applications to be supported by a lower level of empirical evidence, the overall requirements for strategic management and feedback mechanisms should be the same.

In order for the same industry to also be sustainable in economic and social terms, greater consideration should be given to how harvesting rights should be allocated. This should be

informed by appropriate economic research. At present, the first come approach may mean that the opportunities for the regulator to influence the shape of the emerging industry is compromised.

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