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Short Communication

Comments on 'Prospects for the use of macroalgae for fuel in Ireland and UK: An overview of marine management issues'

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ABSTRACT

Terrestrial crops for biofuel may make a negligible contribution to net greenhouse gas emissions [1,2] and may cause other environmental impacts such as reducing freshwater resources and food security [3]. In light of these facts there is increasing interest in the production of marine biofuels [4,5], and so the recent paper in Marine Policy by Roberts and Upham [6] reviewing the cultivation and harvest of UK and Irish seaweeds for biofuels is very pertinent and timely. However it contains a number of factual errors that need correcting and raises several issues, which need fuller clarification. These issues centre around three main themes: (1) a confusion between the occurrence and harvest of intertidal and subtidal species, (2) the relative suitability of seaweeds, and their source (wild harvest versus culture) as feedstock for biofuel generation and (3) an appreciation of the scale at which macroalgae would have to be produced to make any impact on biofuel targets.

1. Intertidal and subtidal seaweeds: wild harvest.

Throughout the article the authors confuse intertidal macroalgae with the occurrence of subtidal 'kelp' beds. The macroalgae of these contrasting habitats (intertidal and subtidal) are distinctly different in terms of their species assemblages, as are the methods of their collection and the ecological implications of harvesting them. As such it is vitally important to make clear the distinctions between the type of seaweeds that are hand harvested traditionally and those which are most suitable for conversion to biofuel and to appreciate that these are two non-overlapping groups.

Although not defined in the article it is taken that wild harvest means the collection of attached material from its primary habitat. The authors state that the "mechanical harvesting has been outlawed and all current harvesting is done in a traditional manner by hand". This statement is incorrect and misleading. The intertidal macroalgae *Ascophyllum nodosum* is currently harvested commercially in Scotland (Lewis and Harris, Hebridean Seaweed Company) by a combination of mechanical and hand harvesting [7], while in Ireland the wild harvest industry is largely based on the hand harvesting of the intertidal species *A. nodosum* for the state owned Arramara Teoranta [8]. With regards to subtidal seaweeds, in the UK, mechanical harvest has been 'outlawed', but there is virtually no harvesting industry, either hand cutting or mechanised.

The authors state a consensus amongst the interviewees that "mechanical harvesting would have a greater impact than hand harvesting, but that the impacts would not be as damaging as other aquaculture industries such as scallop dredging". This is unsubstantiated and meaningless unless it is put in context with current scientific literature and the affiliations of the interviewees, which are not mentioned at any point. It is also important to note that wild harvest is not an aquaculture industry and neither is scallop dredging as is stated by the authors. Furthermore in their comprehensive reviews of this subject neither Kelly and Dworjanyn [9] nor Bruton, Lyons [8] conclude or recommend wild harvest of intertidal species as a potential or a likely source of macroalgae for biofuel generation, regardless of the degree of mechanisation. It is true that a blanket ban on mechanical harvest may well be perceived as a barrier for expanding the wild harvest industry [6]; however, this statement does not hold true in terms of the seaweed biofuels industry in general. Harvest of a cultured biofuels crop would likely consist of mechanised stripping of seaweed from suspended rope substrate. For subtidal seaweeds there is also reason to doubt the sustainability of wild harvest as a source of biofuel feedstock. Research [10,11] from Norway, suggested that, depending on the location, the biomass of subtidal *Laminaria hyperborea* can recover within the 5 year trawling cycle. Unfortunately these estimates refer only to the recovery of the plant itself. It does not take into account the ecosystem effects of harvesting, such as the impacts on invertebrates, fish and

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birds, which depend on kelp canopies and associated beach-cast kelp for food and shelter. Recent research has linked wild harvest of kelp in Norway to detrimental impacts on fish abundance and the foraging efficiency of birds [12]. However the impact of harvesting seaweeds, mechanically or otherwise, specifically grown for biofuels has yet to be fully assessed.

When estimating the available biomass for biofuels the author inaccurately reference Luning and Pang [13] as describing the extent of the wild macroalgal resource available around UK. This reference makes no mention of Scotland or Ireland and certainly does not have any estimates of the current standing stocks of kelp beds. It would be more useful to reference the extensive surveys conducted by Walker from 1947–1954 as reviewed by Kelly and Dworjanyn [9] and to highlight the fact that although 60 years old these are by far the most accurate estimates we have for the UK. Although the natural stocks of macroalgae may seem large from literature values, it should be noted that the actual biomass available for harvesting would be considerably lower. This is because of both sustainability and logistical considerations. One of the major limiting factors in up-scaling wild macroalgal harvest would be the number and location of landing sites and ports required, as well as the cost of transport to processing facilities. Much of the macroalgal biomass is found in remote coastal areas with limited transport infrastructure, and considerable input would be required to allow development of the industry [14].

The authors state that there are essentially two methods for obtaining macroalgae, that of harvesting natural stock or cultivation. It is, however, worth mentioning that there is a third method for gathering macroalgal biomass, one which has a long history in the UK and Ireland, and that is the collection of storm cast weed from beaches. Although it could be argued that this is a subset of wild harvest, the environmental, economic and management issues of collecting beach cast weed are sufficiently separate for it to warrant consideration distinct from that of wild harvest. The implications of collecting storm cast macroalgae are significant, specifically in terms of its impact on sandy beach ecosystems and the impact for migrating birds [15]. However, it poses as the most readily available feedstock for the generation of biofuel on a small, localised scale. It is particularly attractive for remote island communities, both on the west coast of Scotland and Ireland, where little capital and infrastructure is required to remove it from the shore. Interestingly collection of storm cast macroalgae is also not currently constrained by the same legislation that bars the extraction of living kelp. In terms of biofuel production it is worth noting that the biomass of beach-cast seaweed available is a fraction of the living material found in both the intertidal and subtidal zones, and would unlikely to be available in sufficient quantity to allow larger scale exploitation of this resource to be environmentally or economically sustainable [7].

2. Cultured feedstock

The other option for feedstock generation is the cultivation of macroalgae. The seaweed species in the authors list are subtidal large brown kelps of the order Laminariales and it is these which have been identified as having the greatest potential for bioconversion to energy [9,16]. It is worth noting that there is little wild harvest of these species in the British Isles and some are readily culturable [17–20]. In discussing these seaweeds it should be noted that (a) *Laminaria ochroleuca* distribution is limited to the south-west coast of England (b) UK kelps can only be considered 'relatively small (up to 3 m) ' in comparison to the *Macrocystis* species of the Pacific (c) that *Laminaria saccharina* is now *Saccharina latissima* and (d) for the discussion of culturable large brown algae with potential for marine biomass in Ireland and UK, *Alaria esculenta* and *Sacchorhiza polyschides* should also be included [21].

The authors raise a number of environmental, economic and regulatory concerns over the culture of macroalgae for biofuels. In Table 1 the points regarding the introduction of invasive species, competition with other users, advancement by precautionary principle, and unforeseen ecosystem effects and connectivity are well made, however, it is worth noting seaweed cultivation may also have some positive effects on inshore ecosystems. These include restriction of fishing activity, particularly with mobile gear, potentially enhancing fish stocks; provision of additional nursery grounds and a reduction in nutrient loading. The comment made in Section 5.1 that there is an increased chance of eutrophication as the macroalgae decomposes is unfounded. Growing and harvesting of macroalgae removes nutrients from a system, reducing nutrient loading and therefore the possibility of eutrophication [22–27]. In addition, where mussel longline culture structures have been studied (and in terms of marine infrastructure this is the closest analogue to large scale macroalgae cultivation we have) it has been shown that an increase in floating structures allows seabirds to rest and perch, protected from shore predators and human disturbance [28]. Table 1 also raises the risk of invasive species. However, if indigenous kelp species are being cultivated (as proposed in section 5.1) then there is minimal risk.

The authors state that the 'environmental impact of macroalgal cultivation may be mitigated if coupled with existing aquaculture', but do not state how. It is possible that macroalgae can offer some environmental remediation of the existing fin-fish aquaculture operations but not vice-versa. However the authors rightly note possible synergies with other offshore renewable energy industries (Section 4.4). The potential linkage of offshore wind farm and seaweed cultivation was recently reviewed by Stanley, Black [29]. The main issue is, that although carried out on a test scale at sites in the North Sea, [30,31] there are likely to be resource conflicts and an incompatibility in operations. Combining the two is attractive but it must be remembered that not every site chosen for off-shore wind farms will have the appropriate environmental conditions required for seaweed cultivation.

In the section on governance the authors state that at present it is extremely difficult to obtain a licence for any type of aquaculture. This is simply not the case, as the continued expansion of the industry demonstrates. Licensing of new aquaculture developments are proceeding apace in Scotland, albeit within a tightly regulated framework. The legal framework for licensing the cultivation of seaweeds already exists and in UK there is a general willingness amongst regulators and stakeholders such as The Crown Estate to develop seaweed cultivation. Marine Licences have already been granted under the Marine (Scotland) Act 2012 for seaweed culture in an integrated context in Scotland and as stand-alone seaweed farms in Ireland (A Rodgers pers comm; [32]). In terms of economic feasibility the assertion that the production costs for marine biomass production will be significantly higher than for land based developments, are totally unsubstantiated. The economic efficiency of coastal aquaculture is evidenced by the majority of the production in UK and Ireland being at sea rather than on shore. In fact the economic feasibility of large scale macroalgae cultivation for bioenergy remains completely untested. As such the authors statement that the main benefits of wild harvest relative to cultivation are that the costs are much lower is also completely unsubstantiated as there is no available comparative economic analysis to justify this statement.

3. The scale

The authors have underestimated the current scale of the global seaweed production, the current extent of the domestic cultivation and the scale of production that would be required for macroalgal biofuels to make any significant contribution to the national energy requirements. They underestimate the scale of the global seaweed industry using figures for production that are nearly a decade out of date. Estimates for the production of seaweed in 2010 [33], the most upto date figures available, put global production at 19 million tonnes (as opposed to 8 million as stated) and the production of *Laminaria japonica* is 6.8 million tonnes (as opposed to the 4.2 million tonnes). A fuller appreciation of the current scale of kelp cultivation in Scotland and Ireland would have also been appropriate here [19,34,35]. Interested readers should note the recent publications: Edwards and Watson [20], Watson and Dring [32], Walsh and Watson [36] Walsh and Watson (2011). They also present a stakeholder opinion that the cultivation of 'kelp' is not needed due to the level of natural availability and that the market was 'saturated'. In Ireland this statement may well be correct in terms of the availability of intertidal seaweeds to meet the needs of the fertiliser/animal meal although our impression from discussions with the Scottish stakeholders is contrary to this (Hebridean seaweed pers comms). However the stakeholder (and authors) fail to grasp the scale of production required before seaweed biomass could make even a small contribution in terms of energy supply; a biomass far beyond that supplied by natural harvest of intertidal or subtidal beds would be required [9,37,38]. Even using very optimistic estimates of production and conversion to ethanol an area of 2500 km^2 would be needed to provide 50% of the EU ethanol demand [21]. Though this seems relatively modest it would represent 25% of the global sea area currently under aquaculture production [39], and as such would mean a massive expansion of the aquaculture industry of UK and Ireland on a truly unprecedented scale. Although work to fully quantify the natural subtidal resource is on-going, as is the extent to which drift or storm cast seaweeds might contribute biomass, the culture of the large brown sub-tidal species will likely be the only way to secure long-term supply at a scale that makes any significant contribution to energy demand. This level of expansion would bring a set of environmental, economic and regulatory issues that goes beyond those described in the recent article and would perhaps fundamentally change our relationship with the marine environment, from a natural environment in which we hunt (fish) to a pastoral environment on which we farm.

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