

TITLE

Appreciation through Use: How industrial technology articulates an ecology of values around Norwegian seaweed

Abstract

This paper offers a moral history of the industrialisation of seaweed harvesting in Norway. Industrialisation is often seen as degrading natural resources. We argue that it is precisely the scale and scope of industrial utilisation that can provoke non-instrumental valuations of natural resources, and that utilisation can create awareness of non-instrumental values of marine environments. We hope to nuance the common juxtaposition between industry and nature through an account of the historical emergence and transformation of values around seaweed harvesting in Norway. *Sea-weed* became increasingly interesting to harvest as a *fruit* and then as a *crop* of the sea in the early 20th century in Norway, following biochemical applications for alginates derived from seaweed. When harvesting was mechanised, however, regulatory attention turned to the environmental and aesthetic value of kelp *forests*. Further, the sale of the industry to American owners flagged the national value of these plants. In sum epistemic, aesthetic and moral appreciations of natural resources are tangled up and co-evolve with their industrial utilisation, in an ecology of values. Our account builds on historical analyses, public documents, interview and ethnographic material from key sites in Norway.

*Don't it always seem to go
That you don't know what you've got
Till it's gone*

From *Big Yellow Taxi*,
Lyrics by Joni Mitchell

1. Introduction

Industry is traditionally seen as an enemy of environment. Certainly, the discussion has changed from early 20th century debates between Muir and the citizens of San Francisco on conservation (prudential land utilisation) versus preservation (no human interference). Since the 1970s, environmental debates have focused more on “parks versus people”, i.e. on protecting the biodiversity of specific geographic areas, while at the same time allowing for the (economic) development of local populations inhabiting these regions –what is dubbed the “new conservation debate” by Minter and Miller (2011). In this paper we argue that utilisation can create awareness of non-instrumental values of marine environments, and not only in small, native communities. We nuance the common juxtaposition between industry and nature through a moral history of the industrialisation of seaweed harvesting in Norway proposing that technological industrial work designed to “source” instrumental values from seaweed, makes visible the non-instrumental value(s) of these plants, for example as natural habitats for fish and other flora, as aesthetically pleasing marine landscapes, or as living organisms of value in themselves. Perhaps we can think of this story as another layer in hermeneutics: of how dual processes have manifold seemingly opposing impacts. To paraphrase Joni Mitchell, “we don't appreciate what we've got till it's changed”.

We introduce three new but interrelated ideas to the debate: first, the metaphor of an “ecology of values”, second the notion of “appreciation” and third a process of “techno-value” change. First, we use the metaphor of an “ecology of values” around seaweed to convey an array of values which develop and change alongside the marine and industrial systems utilising these plants¹. We identify developing appreciations, as follows:

- Seaweed appreciated as ‘weed’ to seaweed appreciated as a ready-to-pick ‘fruit’, and, further, as a ‘crop’ of the sea –of material and economic value;
- Seaweed appreciated as a crop ready to be ‘harvested’, to seaweed appreciated as a ‘forest’ habitat for fish and other marine life that is to be preserved –of ecological value;
- Seaweed appreciated as a ‘forest’, an ecosystem of value in-itself, to seaweed appreciated as an object of beauty –of aesthetic value;
- Seaweed appreciated as a commercial resource, to seaweed appreciated as a ‘national’ resource –of symbolic and political value;

¹ We concede with Weston's (1985, 322) pragmatic approach to environmental ethics, and discuss this in our concluding remarks here. We concede with Weston's (1985, 322) pragmatic approach to environmental ethics, and discuss this in our concluding remarks here.

- Seaweed appreciated as raw material for industry, to seaweed appreciated as an object and a source of scientific knowledge –of epistemic value.

We use the concept of ‘appreciation’ to capture interconnections between three important value domains. In common parlance, “appreciating x” can mean one of three things: 1. fixing a price for x, or estimating its material value; 2. making a moral, or other, value-judgement of how good or useful x is, or 3. understanding x more fully, in more detail or depth. We use “appreciation” to keep these three strands of meaning together: valuations occurring along an economic-material dimension, a moral and an epistemic dimension, *at the same time*. Through industrial development, humans come to *appreciate* natural environments in their material, moral and epistemological worth.

This is not a one-dimensional process of adding monetary or commercial value to seaweed while impoverishing its ecological worth. Technological development impacts an array of analytically distinguishable yet practically entangled value domains –what we think of as an ecology of values, in a process of “technovalue change”. Developing appreciations though described as if emerging sequentially above, are tangled up in a dynamically intertwining union, developing alongside the issues at stake.

The paper has three main sections. We first offer a historical account of how appreciations of seaweed evolve as industrial harvesting develops in Norway (Section 2). We investigate the development of the alginate industry in Norway, which has been separate from food and food meal applications. We then situate the account theoretically, and connect this analysis to recent discussions of how technology and morality co-evolve. We build on Swierstra’s (2013) notion of technomoral change to discuss technovalue change (Section 3). The last section offers some reflections on the sustainability of seaweed harvesting in Norway (Section 4). Research for this paper was undertaken as part of the Ethical Legal and Social Aspects component of a scientific project on the development of marine-based polysaccharides. We thus rely on empirical material from interviews and research visits with our scientific and industrial partners, where appropriate.

2. Value transformations through material transformations: Seaweed harvesting in coastal Norway

Seaweed harvesting has had a long history but a poor historiography. Perhaps because of its humble origins, and like land farming before it, seaweed harvesting has so far escaped the attention of philosophers (cf. Thompson 1995). Corroborating the centrality of biotechnological development, much of the source material on the history of seaweed exploitation is available through websites and publications of the commercial industry². The work of Mentz Indergaard offers one of the few historical accounts of the development of seaweed-based production of seaweed meal and alginate in Norway, available in Norwegian. What follows draws from Indergaard (2010) informed by academic publications, online material, and policy documents, relating where relevant to our empirical material from industrial and research sites in Norway.

2.1 Early history: Utilising seaweed

Seaweed was utilised by local populations long before any harvesting processes were in place. Seaweed gets regularly washed out by storms on Norwegian shores, making it amply available to

² For instance Kerry healthcare; Ireland industry; SOFIA corporate report.

pick up. In the early Viking period, seaweed was used to feed animals, to occasionally supplement human diets and as a fertiliser for soil (Indergaard 2010, 50 - 57). Seaweed ashes were used to produce potash (potassium carbonate) and soda ash (sodium carbonate) that were used for cleaning (in bleach, or soap), to make glass, or as fertilisers (Indergaard 2010, 65-70). In coastal areas the production of “kelp” (the ashes of large brown seaweed) was of major importance for the glass industry in the 18th century, and later for iodine production in the 19th century. The drastic decline in the world market for iodine during 1933 brought a crisis to Norwegian coastal communities, and caused the first public financing of seaweed Research & Development in Norway (Lunde 1937).

An alternative use for seaweed was alginate production. Norway is one of the world’s top alginate producers, with a history of 70 years in the commercial harvesting of seaweed³. The first Norwegian seaweed gum⁴ industry was established in the early twentieth century, based on the discovery of the British chemist E.C.C. Stanford, first patented in 1881 (Stanford 1881), and later revised by a series of workers, among them the Norwegian industrial chemist Axel Krefting⁵ (cf. Indergaard 2016; Booth 1977).

Krefting and others at the time believed that seaweed was an extremely valuable national resource that could benefit the then quite impoverished Norwegian society (Indergaard 2010, 103). Despite this vision and existing applications for the material, attempts to set up an alginate industry in Norway remained unsuccessful prior to World War II. Companies were instituted but went bankrupt losing lasting effect, until there was a clear market share and relevant chemical research in place⁶. Still, what occurred in this phase was the early industrialists’ and local communities’ appreciation that seaweed is something other than stuff just washed out by storms, a *weed*. Rather, and increasingly as industry grew, seaweed would come to be industrially and publicly appreciated as a *fruit* and as a *crop* of the sea, worth harvesting in the wild. Technology developed alongside knowledge of the biology of the seaweed itself.

2.2 Some biological characteristics of seaweed

The seaweed plants currently exploited commercially in Norway belong to the orders Laminariales (subtidal brown seaweed) and Fucales (intertidal brown seaweeds). We focus on the species *Laminaria hyperborea* (English vernacular: redware) currently used for alginate production in Norway. . At first, modern commercial harvesting in Norway targeted the species *Laminaria digitata*. *L. digitata* grows in the topmost part of the subtidal and can be accessed at low tides, and it has a flexible, rather thin stem or “stipe” possible to cut manually. However from the mid-1960s on, and now almost exclusively, commercial harvesting focused on *Laminaria hyperborea* (Figure 1). Mechanised harvesting provided access to a high-value alginate material found in the stipe of *Laminariales* of which *L. hyperborea* have a thicker one.

³ For example, the site of FMC <http://www.stortare.no/?service=tarehosting-en-del-av-norsk-kystkultur>

⁴ Cf. http://www.seaweed.ie/uses_general/industrialgums.php

⁵ See his patent at www.google.co.uk/patents/US598790

⁶ A Norwegian seaweed meal producer (mainly intended as fodder additive) started with Algea Produkter A/S in 1937, and is still in operation, now owned by a foreign company.



Figure 1. *Laminaria digitata* (left) and *Laminaria hyperborea* (right)⁷

L. hyperborea form dense beds (also called “kelp forests”) that have a rich understory of flora and fauna. *L. hyperborea* individuals have a rigid upright stipe of about 1–2 meters and can reach up to 15 years of age. They are not adapted to strong wave impact, so they can break up relatively easily but they are able to grow with even 5 % surface light, and at 30m depth in Norway. They have large “blades”, which create a lot of shading for the flora and fauna underneath them, and that are striated to accommodate for the mechanical strains caused by wave impact (Werner and Kraan 2004, 5). Like other seaweed plants, *Laminariales* attach to the seafloor through a “holdfast”. This looks like the root site of a land plant, however its function is only to anchor the plant securely on the seafloor. Seaweed plants receive nutrients instead through their whole body, and only the largest species have some rudimentary internal sieve tubes/channels for mass transport.

The biogeography of kelp depends on seawater isotherms and seawater composition that influence the reproduction and survival of the seaweed. Reproduction happens in two stages, one asexual and one sexual, which relies on the dispersal and fertilisation of *sori*. These are released by the plant early in fall, become fertilised and “hibernate” until sunlight starts returning in February. The dispersal of *sori* can reach up to 200m area, and it is crucial for reforestation after harvesting (Werner and Kraan 2004, 9) –cf Figure 2.



⁷ Photos available at <https://www.flickr.com/photos/cdbio94/3100457787/>;
<http://cavemanchemistry.com/oldcave/projects/potash/>

Figure 2. Drawing of the reproductive cycle of seaweed hanging in a corridor of the Biology Department at the Norwegian University of Science and Technology, NTNU. (Photo: author's own.)

2.3 Harvesting: from weed to fruit and crop

“Seaweed is no longer a weed”: thus begins a special section in the magazine “Norway Exports” published quarterly by the Export Council of Norway (Norway Exports 1962, 62-66) (Figure 3).



Figure 3. Excerpt from Norway Exports Fall issue of 1962, one year after the opening of the new alginate factory in Haugesund in 1961. Notice the depicted involvement of local people, women, and men manually harvesting seaweed. The caption on the top left and bottom right images reads “Many people earn an extra income gathering... ..and transporting the seaweed in summer” (p.62).

The editorial captures the new value imagined of seaweed: “Weed it is called, but among vegetation the various varieties of seaweed are unique in composition and utilisation. Here many believe is a form of vegetation the potentialities of which have scarcely been touched” (Knudsen 1962, 27).

The institution of a new industrial alginate plant in Haugesund in the South-West of Norway, in 1961, increased demand for higher volumes of seaweed raw matter (Vea and Ask 2011, 490). Seaweed was initially harvested manually, from shores or from a boat using a seaweed net. This involved using a long pole with a blade and net attached to it, from a small open boat. This was “like the net we use for picking berries in the forest” (B1 interview) –coherent with an appreciation of seaweed as a *fruit* of the sea. As mentioned already, of the two *Laminariales*, *digitata* was easier to process chemically and easier to cut; yet *hyperborea* was targeted for harvesting as demand increased for larger quantities of raw material found in the stipe. *L. hyperborea* were large plants whose harvesting could be mechanised, offering a way to increase resources rapidly.

The mechanisation of seaweed harvesting happened progressively but had a big impact on industrial harvesting capacities and on how seaweed would come to be appreciated anew, as a *crop* of the sea.



Figure 4. Three dredges and a berry picker. Top: early mechanised dredge with features combining that of a net and trawler (Adapted from Veia and Ask 2011, 490). Bottom left: Some newer trawlers displayed outside the Haugesund factory (author's own). On the commemorative plaque on the right we read that the tindetrålen in the back is one of the first to be developed "through a collaboration between the trawlers and the company". It had a design that "revolutionised harvest and made it possible to fill up boats fast and effectively". It lies on stones taken from the bottom of the seafloor that were removed in the wash basin and kelp cutter. Bottom right: Metallic berry picker from the 1980s (author's own).

The alginate industry developed the first mechanised dredges in the early 1960s, creating a sled/trawl that was to be towed behind a boat, which kept but added in size to the manual tools. Like the manual device, this early system had a blade for cutting the seaweed, leaving the holdfast intact (Figure 4, top). By the 1970s dredges took on their current form, and purpose-built "seaweed trawlers" were developed. The modern dredge has eliminated the blade, and rather pulls seaweed up along with the holdfast (Veia and Ask 2011, 490), utilizing the whole plant. Smaller plants of less than 20cm, that are younger, are left intact, though the flora and fauna of the kelp forest is affected by the harvest. Modern dredges can pick up to two tonnes per haul, with each haul taking from a half to two minutes to complete. Trawler boats have a capacity of 30 to 150 tonnes, and they operate in depths between two and twenty meters.

There are currently 11 seaweed trawlers that operate in service of the major industry agent in Norway, FMC Food and Nutrition (formerly FMC Biopolymer). The trawlers work along the coast of Norway, from the county of Rogaland in southern Norway to Sør-Trøndelag in the middle of the country and harvest on average 130–180 thousand tonnes of seaweed (wet weight) a year. The harvest amount depends on market demand and weather conditions. The operators of seaweed trawlers are paid directly by the industry in Norway, unlike for example in France.

Measurements undertaken in the 1950s and 1960s along the coast of Norway and up to Finland in the North established the total biomass for sublittoral phaeophytes to be at minimum 15 million tonnes of which at least 10 million tonnes was *L. hyperborea* (Werner and Kraan 2004, 21; see also Indergaard and Jensen 1991). The period of mechanisation saw a great increase in the harvest of *L. hyperborea*: from 1973 to 1984 the production increased from 118 thousand tonnes to 170 thousand tonnes of annual seaweed harvest. In recent years the harvest has been between 140 and 180 thousand tonnes per year (Werner and Kraan 2004, 22).

2.4 Mechanisation and controversy: seaweed as kelp forest

With the utilisation of mechanised ways of seaweed harvesting, different regulatory and environmental issues came to the fore (Veia and Ask 2011). At first, the main tensions up for negotiation occurred between local fishers and the trawlers, as fishers were concerned that harvesting affected their fish yield, both directly and indirectly where a temporary reduction of kelp forests might lead to a more exposed coastline. Kelp forests are a breeding ground and food resource for some, mostly non-commercial fish species, besides several other species of fauna and flora.

We have not interviewed fishers. Industry and research staff however claimed that the relative ease of trawling created further tensions between trawlers and fishers (Interview I3; H1). Fishing had to be undertaken at odd times of the day, in the open sea instead of the fjords, at a personal risk for one's safety and with variations of fishing yields and payment. Instead, trawling could be done at an 8-4pm workday cycle, in safer waters, and with a more regular yield and payment. Whether the conflict between these two work cultures concerned more than the management of marine resources is unclear. Still, industrialisation transformed the livelihood and social worlds of marine professionals.

Seaweed harvesting is currently regulated by the Ministry of Fisheries and the Directorate of Fisheries (DOF) who develop regulations in consultation with the Directorate for Nature Management, under the Norwegian Ministry of the Environment (Indergaard 2010, 45-46). Following concerns from fishers, the first official study of seaweed harvesting impact was conducted by the University of Bergen and completed in 1972. The same year, the Law of Saltwater Fisheries included the first public regulation of seaweed harvesting. It established a 4-year harvest cycle, revised to a 5-year harvest cycle in 1992. In 1995 the Norwegian Ministry of Fisheries solicited a report that was completed in 2000, to help plan the long-term management of seaweed harvesting. Since 2008, the management of seaweed falls under The Marine Resources Act, aiming to “ensure sustainable and economically profitable management of wild living marine resources and to promote employment and settlement in coastal communities” (Havressursloven 2008 §1). It seems

that currently seaweed trawling is not affecting fish yields in Nord-Trøndelag (Steen et al. 2012), but that need not imply that there are no other environmental impacts to trawling.

Seaweed harvesting is allowed all year-round in Norway, though periods of seaweed harvest are coordinated with fishing cycles, so as to avoid overlap and conflict. The current practice of harvesting already set up in 1972 involves dividing the harvest area into plots that are 1 nautical mile (1.85 km) wide, and that may at certain parts of the Norwegian coast run a few kilometers into the sea, down to 30 meters of depth. Harvesting these plots follows an alternating cycle so that fields harvested one year are not neighbouring the fields harvested the next year (figure 5). For each of these fields there is a 15–20 % biomass removal by harvesting, while 10–20 % of biomass is removed by storms and waves. The harvesters are issued licenses of up to five years to harvest, which can be revoked or banned by the ministry. Trawlers have to notify the coast-guard police and fishing authorities with their harvest plan one month ahead of schedule and keep a harvesting diary. During the seaweed harvest, fishers are expected to give priority to seaweed trawlers, though seaweed harvesting is arranged so that it does not coincide temporally and spatially with fishing activities.

Several issues regarding the sustainability of seaweed harvesting became aggravated with the mechanisation of harvesting and the thousand-fold increase of the harvest yield. First, harvesting using seaweed trawlers cuts lanes through the kelp forest as opposed to cutting individual plants, affecting the ecosystem more radically. Secondly, though the harvest cycle for *L. hyperborea* is 5 years (and reverted back to 4 for some regions in the South) *L. hyperborea* can reach up to 15 years of age naturally, suggesting that though the harvest is shown to be sustainable, i.e. yielding similar amounts of seaweed wet weight for the industry for now 30 years every year, it is not clear that the kelp forest is allowed to fully regrow within these five years (see also Steen et al. 2016, 65). Overall, only 0,3% of the total Norwegian *L. hyperborea* forest is harvested annually, while 10–20% is destroyed in storms. Still, local effects on fish and other underwater life in the harvested plots may be significant as up to 40 % of biomass removal occurs in these plots which may affect the broader area. As such, there is a recognised need for more knowledge about the impact of harvesting (Steen et al. 2014). For precautionary reasons Seabird Protection Areas have been designated and seaweed harvesting is currently forbidden there during the birds' breeding season.

Further threats to the seaweed harvest include, besides excessive harvesting and storms, warm-water events and the activity of the green and red sea urchins, respectively. Climate change and rising seawater temperatures are a growing concern in Norway, as elsewhere. The temperature of deep waters in the Norwegian coastal current is still, since the 1990s, 0.7 °C above normal (Aure 2016, 40-42). Seaweed die-off has been recorded after especially warm summers, as in 1997 and 2002. The green herbivore sea urchin is responsible for grazing down kelp forests in the northern coast of Norway, while the red sea urchin is observed in high numbers in less dense *L. hyperborea* beds in the southern regions. Note that, though sea urchins have devastated the kelp forest along almost all of Northern Norway, fishers have not complained about this type of “natural” action of seaweed grazing as affecting fishing yields (Sakshaug et al. 2002).

Studies in southern Norway along the north Trøndelag region suggest that more time than the current cycle of five years is needed for the restitution of kelp vegetation in harvested areas: “kelp stipes and epiphytes were not fully developed until the plants were approximately 8 to 10 years old”

(IMR 2016, 65). There has been some reaction from local politicians following this report. In a long-standing opposition to the seaweed industry in the Sogn og Fjordane county, political representatives of the Bremanger municipality motioned the Directorate of Fisheries to ban seaweed harvesting in the Bremanger fjord, over concerns that industrial interests are being prioritised over environmental interests (Andersson 2016).

2.5 Seaweed as a (beautiful) thing in itself



Figure 5. Left: An image of *L. Hyperborea* kelp forest hanging on the wall of the Haugesund factory of FMC; Right: high value alginate is found in the stipe.

The 1960s and 1970s, the period when seaweed harvesting regulation was formed, was also a period of intense intellectual production for ecological science and philosophy in Norway (Anker 2007). The so-called “deep ecology” philosophy (Næss 1973) influenced the public awareness of issues concerning the intrinsic value of nature and the potential for human destruction through industry. Intense political discussions were had regarding the creation of the first Norwegian national parks (from 1962 to 1971) and new hydroelectric power plants and dams in that period (Anker 2007, 456). Though this did not directly involve marine parks, and activities undertaken in the sea, it created a broader public awareness of the aesthetic and possible intrinsic value of natural environments.

Besides securing information regarding the marine ecology of seaweed systems, research into the life of seaweed plants helped articulate these types of value. Seeing kelp forests in the wild, depended on the right technology, developed in part to respond to requirements for regulating trawling made by fishers, but also alternatively used as a leisure technology and as a means of promoting ecological consciousness.

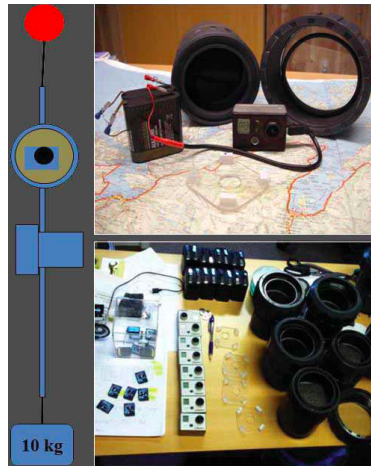


Figure 6. Fixed camera systems: weighed to the bottom of the sea, with a 10kg weight, and buoy on top cameras with exposures in different directions are used to track sea life. (Adapted from Effekter (2013, p11 fig 5). GoPro kamera, kamerahus og kamerarigg).

Monitoring seaweed plants' growth implied using equipment that afforded a view into the seaweed forest presumably, as it is in itself, in the wild (Figure 6). Specialised camera equipment, either weighted to the bottom of the sea or carried down by divers was used to document in photos and film the life of underwater kelp forests. Scuba diving technology, through its development, from a risky military or industrial enterprise to leisure pastime has been active in disclosing underwater worlds to scientists, but also to the public.

There are still frequent accounts of the beauty of kelp forests in Norwegian newspaper articles, blogs and other media –for instance, we hear of the underwater life captured during the diving courses of Jan Roar Gjersvold in the fjord around Trondheim (Fikse Ness 2014), or of a marine biology research excursion contrasting “grand” seaweed forests with “sad sea urchin deserts” (Bekkby 2015). Triggered by technical and industrial advancements, then, the increased focus on life beneath the surface through the monitoring of the effects of harvesting and the increased public ecological concern, increased an awareness of kelp forests as values in themselves, as ecosystem resources and as objects of aesthetic appreciation.

2.6 A Norwegian national resource: Or a commercial one?

A further dimension along which industrialisation impacts an ecology of values around seaweed is the political value of this resource as national, Norwegian product. As already mentioned, the alginate industry in Norway used to be owned and developed by Norwegian entrepreneurs. Their activity was generally considered as nation building, following the independence of Norway from its union with Sweden in 1905.

The Norwegian company that would first successfully handle the production of alginate was founded in 1939. It was named A/S Spesialimpregnering, as it produced life vests impregnated with latex. When the Second World War started, the owner, Haakon Kierulf, did not want to profit from the war, especially after the Nazis occupied Norway. Prioritizing national over commercial interests that the production could serve, the company phased out life vests and turned to producing other latex-impregnated products. Soon there was a shortage of latex, and the production started replacing latex with alginate derived from seaweed. This was a success, and continued with using alginate as a

substitute in other products, such as soap, toothpaste and jam. The company profits were invested in research on alginates under a new sister-company name, A/S Protan. In 1943 Protan scientists managed to produce pure sodium alginate. Although other Norwegian companies attempted alginate production after the war, Protan emerged as the one successful company, gradually establishing a monopoly in Norway and becoming a world-leading producer of alginate (Indergaard 2010, 106-107). Thus the political interest in withholding an income from Nazi government tax indirectly enabled the scientific and further economic development of the industry.



Figure 7. Advertisement of Protan products from 1962 and image reproduced from a current alginates brochure of FMC Biopolymer (2015).

Protan realised the vision of the alginate industry pioneers of exploiting the values of this unique national resource. An advertisement from 1962, when the market share of Protan was well established reads: “Selected seaweed from *nature’s inexhaustible sources* –the *fertile coast of Norway*– is the raw material for the famous thickening, stabilising, gel- and film-forming agents produced by A/S Protan” (Norway Exports 3/1962, 5 –*emphasis added*; figure 7, left). The company advantage is still closely linked with *L. hyperborea* that grows in abundance along the Norwegian coast –though it is no longer considered to be inexhaustible. This is considered to give a national advantage to a Norwegian-based alginate industry. As one of our interviewees emphasises: “This [kelp] is specific to this [Norwegian] coast – and that is why the Chinese cannot compete with us”(B3). Note that even if the kelp proliferates in Norway it grows from Northern Spain to Iceland.

Gradually the ownership of Protan got out of Norwegian hands. In 1980 was acquired by Norsk Hydro, a goliath of Norwegian industry which was majority owned by the Norwegian government. It later changed name to Pronova and was subsequently acquired by the US-owned FMC corporation in 1999⁸. Our empirical research has been with FMC Health and Nutrition and the medical company NovaMatrix, a spin-off of Pronova, also acquired by FMC in 2005.

⁸ The acquisition is announced here: <http://www.prnewswire.co.uk/news-releases/fmc-agrees-to-buy-alginate-business-from-norsk-hydro-156035115.html>

Attention to “a world of possibilities” that lies “just below the surface”, is still drawn in current FMC marketing publications though not directly identified with a Norwegian context (Figure 8, right). The FMC seaweed processing plant in Haugesund retained many of the same staff despite transitioning into new American ownership. Norway is still benefiting from this industrial activity and our fieldwork indicated that Norwegian employees are satisfied with the American management of the company. However, some tensions remain. As a senior scientist in our project group put it: “Now I work with them [FMC] of course; but I did not like that a company that has some sort of monopoly on Norwegian algal resources was sold out of the country” (C4 interview).

2.7 Science vs. Industry: Seaweed as a source of scientific knowledge

Sheila Jasanoff (2004) has analysed the interdependence of scientific development and socio-political change under the concept of the *co-production* of science and society. Numerous studies of science show how non-epistemic values can influence science and allow scientific productions to be geared towards practical, non-epistemological concerns (Shapin 2008). Take the first British scientist to enter the house of Lords, William Thomson (Lord Kelvin): As Wise (1989) describes him Thomson was directly involved with politics and industry, he founded the first university lab, which was also an industrial lab, and his politics informed the physics of the trans-Atlantic telegraph and steam-engine technologies. Similarly, in the case of the Norwegian alginate industry, we see a close-knit and arguably mutually beneficial connection between industry and biochemical research.

Norwegian-based industries on seaweed have been key drivers for scientific research. As discussed it was partly the investments made by Kierulf into Protan research which resulted in the production of pure sodium alginate in 1943, in return giving the company a market lead. The Norwegian Institute of Seaweed Research (Norsk Institutt for Tang- og Tareforskning, or NITT) was founded in 1949 by the then Royal Norwegian Council for Scientific and Industrial Research (NTNF) and it was directly funded by the research council as an independent institute until 1973-74.



Figure 8. A mark of the identity and history of the NTNU cluster we worked with: an old sign hangs on the inside of the project leader’s door reading: *Norsk Institutt for Tang- og Tareforskning* – Norwegian Institute of Seaweed Research.

The Institute became a vibrant center for alginate research, and the public funding gave the scientists the freedom to really study in-depth the connection between the alginate polymer's rheological properties and its chemical structure.

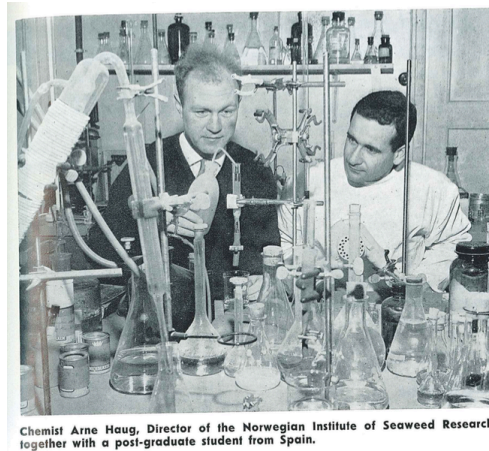


Figure 9. Photograph of work at the NITT lab-bench with the caption “Chemist Arne Haug. Director of the Norwegian Institute of Seaweed Research, together with a post-graduate student from Spain.” (Norway Exports 1962, 65.)

Many of the people studying at the NITT at the time, and at its successor the Norwegian University of Science of Technology, would go on to take positions in the industry or in relevant government regulators, or continue with academic work, making this a small community of basic and applied seaweed and phytoplankton research in Norway (Figures 8, 9).

However connected, academic and industrial research on marine-based polysaccharides can still have divergent motivations. When asked about his motivations for working in academia one of our science collaborators reports:

Curiosity and understanding drives me –that is the key for me. Not so much that society needs that –because then it [research] is linked with money. The company [collaborators] will have those motivations. Here [in academia] it is more about being the first to understand or solve something –Then (there) is the honour behind it and being a part of revealing the truth of its function. That and being curious about things.... Here [in academia] you have the possibility to go on with things even if they would not necessarily be leading to more money. It’s a bit about understanding something and being able to show something -- in a company the interest is in whether something is feasible –if it leads to a better market share –if it is better than their competitors (D1 interview).

Indeed, researchers in industry who we interviewed, voiced concerns with balancing the technical feasibility of applications with their marketability, and patent rights which the industry could get over products.

And research finds may not always align with existing industrial infrastructures. For instance, consider the production of alginate bacterially, in the lab, instead of by extraction from seaweed raw materials. Bacterial production is currently under investigation including in our associates’ project. It is not clear whether bacterial production of alginate threatens to replace the seaweed-based industry in Norway. Still, one might expect that, were bacterial production to be cost-efficient and

effective in producing high quality alginates, American owners would have little reason to continue production in a land with high labour costs and long distances to major markets and where the environmental and aesthetic worth of *L. Hyperborea* kelp forests is at stake.

3. Biotechnology as Value Engineering

Evolving material, moral and epistemic appreciation of naturally sourced materials are, we claim, tangled up with sociotechnical innovation and industrialisation.

3.1 Tang, tare and entanglements

Note that, despite the nice contrast between weed and seaweed in English, the Norwegian word for seaweed has no association with weed, i.e. with a plant that is neither useful nor beautiful. The Norwegian term for seaweed is “tang og tare”, roughly translateable as “fucus and large algae”. The English word *tangle* is derived from the old Norse term which the Norwegian *tang* derives from, meaning “to entwine or entangle” as seaweed do. The Norwegian *tare* is on the other hand related to the English *tender*, meaning delicate, which is dated back to the Indoeuropean term *terk*, meaning to rotate or twist itself. Seaweed then, in Norwegian, conveys not so much the (lack of) use for these plants, but instead their tangled and delicate, twisting natures.

Some key factors contributed to the transformation of seaweed to material of commercial value. Seaweed’s natural properties and the accident of being naturally accessible to coastal populations to pick up following storms already made seaweed available for nutrition and small-scale material applications. In this primal stage of relating to the seaweed, human action was limited to a more-or-less passive reception of this “fruit” of the sea, acting to process it in relevant ways, but not intervening to interrupt seaweed lifecycles in order to benefit human needs. Within that sphere of relation to seaweed humans appear as “downstream” users of these weeds, once indeed sea-weed utility to its surrounding marine ecosystem has become radically limited, and by non-human factors. Though possible to use, eat, burn, and otherwise process, the origins and precise growth-cycle of the seaweed remain mysterious (and mostly uninteresting) to the humans who receive it.

The possibility for the active, coordinated and targeted, manual, and later mechanised harvesting of sea-weed changed local relations to the seaweed and the scope and range of values that may be found in it. By analogy to operations utilised to harvest fish from the sea, boats and specially designed nets and throws were built to harvest vegetation from the sea. This action intervened in an already formed space of values sought and found in the sea. Whereas fish was not a resource that is contested as legitimate to utilise and consume, at least at the time, seaweed harvesting became a sticking point for a changing terrain of values. Seaweed was seen as of essence for sustaining marine flora including fish, and fishers became aware of the value of the material for fish populations –and of the trawling industry for their livelihoods. In this way, acting to harvest seaweed in the wild, at a stage in its lifecycle before it has become detached, transposed from its marine milieu and brought closer to the shores that humans inhabit, made the seaweed visible as a forest.

With an increased understanding of seaweed’s chemical structure and properties opened up new scientific worlds for the cultivation of some of the material values found in the material in the wild, within human-made laboratory environments; supplementing the understanding and re-use of this material in a range of commercial, pharmaceutical, agricultural or food industry applications.

Seaweed became appreciated as a species of *L. hyperborea* and further looked into, broken down into *alginates*, with specific component, of different scientific and practical value for the community of science and industry around seaweed.

In the process of measuring and establishing the ecological interdependencies between seaweed and fish, humans came to meet kelp in their full grandeur and complexity, the thickness afforded to them through their collective natural state. Extensive mapping of coastal sea-life previously superficially engaged with was undertaken. Equipped with cameras, oxygen and measuring tools humans became tasked with figuring out and negotiating some of the at times conflicting values that may be found in seaweed: as food for fish and as raw materials for alginates or other minerals production. At the same time, and especially following the mechanisation of seaweed trawling techniques, seaweed came to acquire value *in itself*. Kelp forests became possible to appreciate, as land forests already before them, as worthy in themselves.

The process of establishing the values of seaweed materials for commercial and natural ecosystems, parallels a process of claiming, forgetting and remembering the significance of seaweed as a Norwegian national resource. Due to its special properties, seaweed found along the coast of Norway was of extra value for the nation, as envisioned already by Krefting and maintained later by Kierulf. This is a resource for building the nation's industry, as well as know-how and scientific understanding of the sea. The national significance of this material gets partly forgotten and rapidly resurfaces once the industry is sold to American owners in the 21st century.

This dynamic "value ecology" co-evolves along with those people, seaweed and other living beings that get tangled and brought to notice as relevant stakeholders in the activities of the industry. But what is the value of such a metaphor?

3.2 Ecologies of value

One way to answer is to relate this metaphor to current discussions of how technology and morality can influence each other. Considering the relationship of science to society has developed from naïve views of technological determinism and instrumentalism, to instead appreciate that social-political imaginaries and technological-scientific knowledge can drive each other's production and need to be considered in tandem, whether because of the metaphysical or because of the practical dimensions of co-production (Jasanoff 2004, 20-21). This thinking has created new modes of producing knowledge about the world (Gibbons et al. 1994), which include ways of integrating Ethical, Legal and Social Aspects research within ongoing scientific work, and developing frameworks for responsible research and innovation (Stilgoe et al. 2013).

Theoretical work on co-production has been driven by social scientists and philosophers of science. We chose to focus on "values". But we are not interested in values as parameters in technology design (van den Hoven et al. 2015), nor in policy-making (Douglas 2009). Rather than assessing how specific types of value guide scientific and industrial practice, we take the opposite direction and investigate how new ways of appreciation, of, in this case, seaweed become possible through socio-technical industrial development.

If we follow Swierstra (2013, 207-208), interpreting Verbeek, technology can influence morality in two ways: First, by influencing our perceptions, forms of knowledge and sense experience of the world, including how and who comes to be considered as morally significant (hermeneutic impact) Secondly, by affecting practical possibilities for acting in the world (existential impact). In our analysis we see how technical means such as photographic equipment is a technology changing morality along a first, hermeneutic dimension, by making visible new stakeholders (marine life) as morally relevant. However the technology used for seaweed harvesting does not primarily have an exploratory, hermeneutic aim. What happens in the case of trawling technologies is that a technology primarily developed to extract material values from the sea impacts in a negative way, or at least throws out of balance, other technologically mediated practices of marine-life exploitation (fishing). Changes crossover an ontological/existential dimension and hermeneutic dimension, besides an economic one.

A technology is developed to maximise material values from seaweed understood as a crop of the Norwegian coast; this is deployed in a wet environment where others eat and swim and comes to function at the expense of/while highlighting the role (and understanding) of the kelp forest, as recreational nature and as a thing in itself. As such, the practical impact of seaweed harvesting technology mobilised in an industrial scale, along with its supporting infrastructures comes to highlight new interpretations or understandings of seaweed. What we see here then is the existential dimension impacting a hermeneutic one which in turn changes the practical demands and requirements made of industry because it occurs in a context of care about marine and human lives (to some, though perhaps different, measures). This highlights a dynamic relation between material, epistemic, and moral value.

Indeed our analysis shows that these may co-evolve and should be studied together. Mapping an ecology of values as we understand it involves considering processes of value-creation, value-transformation and value-obstruction that may mimic, parallel, and in many cases ride on the possibility to socio-technically transform the material parts of a natural ecosystem within current human-made infrastructures. In our understanding, value ecologies like natural ones will partly depend on and condition particular (economic, moral or scientific) appreciations of what are seen as naturally interconnected, ecologically bounded entities and organisms. Our notion of appreciation connects to work done on valuation, instead of values, and the attempt to understand values as part of social-material practices (cf Journal Valuation Studies). However we do not have a social theoretical account of such social practices. Rather, we are interested in what implications such processes have for ethics.

The upshot is a pragmatist approach to understanding values as intrinsically interrelated (Weston, 1985):

The notion of fixed ends is replaced by a picture of values dynamically interdepending [and we would add, developing] with other values and with beliefs, choices, and exemplars: pragmatism offers, metaphorically at least, a kind of "ecology" of values. Values so conceived are resilient under stress, because, when put to question, a value can draw upon those other values, beliefs, etc. which hold it in place in the larger system. At the same time, though, every value is open to critical challenge and change, because each value is also *at stake* precisely with those related values, beliefs, etc. which on other occasions reinforce it.

We are thus left with a plurality of concrete values, in which many different kinds of value, and many different sources of value, can be recognized as serious and deep without requiring further reduction to some single end in itself (322).

The metaphor of an “ecology of values” is aimed to convey such a “living” and “changing” realm of reasons, emotions, meaning and beauty that condition how humans get to find, change, detract or add (different kinds of) value to materials in a natural ecology: to “appreciate” these resources along material, epistemic and moral dimensions. We may call this type of change (or evolution if we want to be optimistic) one of *technovalue change*: technologies and values co-produce each other, not only once it comes to morality (Swierstra 2013, 2015), but implicating both material and epistemic conditions.

4. Concluding reflections on sustainability

Appreciating seaweed as of economic or national value, as of aesthetic and environmental value, or as of commercial and scientific value, all come to the surface, often at the same time as the seaweed itself is being lost, cut, sold, analysed or transformed into new chemicals. But how *should* we regard seaweed now that we are aware of its unique qualities and value both for its own sake and for the life forms that depend on it? Where does this leave a project of critical scrutiny on the ethics of seaweed harvesting?

A standard environmental ethics analysis would distinguish between three main ways of viewing seaweed: (1) instrumentally, e.g. as habitat for fish, interdependent with pelagic fish captured by humans, (2) as intrinsically valuable, as an irreplaceable part of a whole, (3) as a part of a valuable ecosystem that is a whole worth preserving (i) for human utility or appreciation or (ii) for its own sake. Views (1) and (3i) are associated with an anthropocentric ethics, whereas approaches (2) and (3ii) would follow a variety of biocentric ethics. Views (1) and (2) follow an ontology distinguishing between seaweed and humans –whereas in view (3) we could get some ontological tangles. All approaches assume there must be some kind of value in seaweed (or nature broadly speaking) – instrumental or not.

What they do not account for is the transformation of these values into each other. If we heed our account of how different appreciations of seaweed develop, it is the utilisation of nature is that has, historically, disclosed to us its value. Ironically, it seems, transformation is a condition for the further appreciation of nature. This tension we here proposed to see as tangles between the values that seaweed forests create for the fish, birds and local or distant people they are being with and being dependent on, and who in turn are dependent on them. Following Weston our aim is not to “ground” practice in some ethical principles, but rather to situate values in context and to arbitrate their conflicts with others: “a subtle enough difference at first glance, perhaps, but in fact a radical shift in philosophical perspective” (Weston 1985, 322).

If people and parks *change together* we need work to adequately dwell on, and to respond to these changes with an acknowledgement of how interdependent human and natural livelihoods are. A responsible use of nature is one that is restricted by considering the value of nature independent of our use of it, even if we would not come to know what this value is otherwise –to paraphrase Donna Haraway on the use of research animals: we need to keep using nature, while avoiding making

nature usable (Haraway 2008, 69-94). The metaphor of an ecology of values suggests that humans and plants are bound with living ties through which things get made and unmade, and appreciated.

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