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THE CURRENT ROCKWEED, *ASCOPHYLLUM NODOSUM*, HARVESTING REGIME ON THE SHORES OF NOVA SCOTIA – A REVIEW

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ABSTRACT

Ascophyllum nodosum is an ecologically and economically valuable species of brown seaweed found in Nova Scotia. The large fronds covered in airbladders create distinctive underwater canopy ecosystems in the intertidal zone. *Ascophyllum* is valuable as a soil supplement and fertilizer due to its biochemical composition. Commercial harvest of this wild resource began approximately sixty years ago and has been continuously exploited since. Careful management of *Ascophyllum* stocks is necessary to sustain the industry. In this literature review, the current harvesting regime of this seaweed in Nova Scotia is summarized and assessed in relation to harvesting regimes elsewhere and to the state of the intertidal marine ecosystem.

Keywords: *Ascophyllum nodosum*, ecological impacts, intertidal ecology, resource management, rockweed harvesting, seaweed industry

INTRODUCTION

Ascophyllum nodosum (Linnaeus) Le Jolis, commonly known as Rockweed or Knotted Wrack (and herein, *Ascophyllum*), is a brown fucoid seaweed that covers much of Nova Scotia's rocky shores. It is a common species across North Atlantic coastlines, found from Norway to Portugal along European shores (Sharp 1987) and from the Canadian Artic to the Atlantic Provinces, and extending as far south as New Jersey in the United States (Mathieson and Dawes 2017). Commercial harvest of *Ascophyllum* in Nova Scotia remains industrially significant since its expansion in the 1960s, with industrial harvesters continuing to manage the available *Ascophyllum* resource primarily with the guidance of industrial, not provincial, scientists. In this review, the reasons why *Ascophyllum* is a

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commercially and ecologically important species, and the current status of its commercial exploitation, are discussed.

Morphology and Ecology

Ascophyllum propagules settle in the upper to mid-eulittoral zone of the intertidal on rocky substrate, and the fronds grow to cover wide expanses of the shore in dense beds, often with 100% cover. The species does not tolerate high wave exposure and its distribution is typically limited to sheltered areas such as coves and bays (Lewis 1978). The observed southern limits of this species are at 42N latitude, where ocean warming limits reproduction. The species exhibits clear sensitivity to climate change (Pereira *et al*. 2020). The entire thallus of this perennial seaweed can survive for up to 120 years, while individual fronds can persist for up to 20 years (Åberg 1992).

This seaweed can reach up to 2 meters in length and is primarily composed of dichotomizing branches (Baardseth 1970). Dozens to hundreds of new axes can also form directly from the discoid holdfast. This holdfast anchors the entire seaweed to the substratum, typically rocks or boulders. Characteristic egg-shaped air bladders occur at regular intervals along the length of the fronds' branches and primary axes, giving rise to the common name Knotted Wrack. At low tide the thallus lies prone over the substrata, while at high tide the gas-filled air bladders enable the thallus to float, forming three-dimensional underwater canopies (Kay *et al*. 2016). Thirty-four species of fish, thirteen kinds of birds, and one hundred taxa of invertebrates have been observed utilizing *Ascophyllum* as their habitat, some grazing on *Ascophyllum* and its epiphytes, and others utilizing the canopy for protection from predators (Johnson and Schiebling 1987, Seeley and Schlesinger 2012).

Associated with the vegetative fronds, two additional forms of production occur in *Ascophyllum*. The first is the reproductive bodies, receptacles that form in buds along the frond, appearing first as incipient branches before swelling (Baardseth 1970). Receptacles begin developing early in the summer but do not mature until the following year, within a wide period ranging from late winter to early summer. When mature, the total biomass of reproductive tissues produced and released by an *Ascophyllum* thallus into the ecosystem can reach 150% of the thallus vegetative biomass (Garbary *et al*. 2021b). *Ascophyllum* releases male and female gametes from unisexual sporophytes all at once in the spring, with receptacles rapidly dehiscing (i.e., splitting open) soon after (Josselyn and Mathieson 1978).

There are two sorts of production associated with the vegetative fronds in *Ascophyllum*. The first is the formation of reproductive bodies called receptacles; they form in buds along the frond, appearing first as incipient branches before swelling (Baardseth 1970). Receptacles begin developing early in the summer but do not mature until the following year, within the period that ranges from late winter to early summer. When mature, the total biomass of reproductive tissues produced and released by an *Ascophyllum* thallus into the ecosystem can reach 150% of the thallus vegetative biomass (Garbary *et al*. 2021b). *Ascophyllum* releases male and female gametes from unisexual sporophytes at the same time in the spring, the receptacles rapidly deteriorating and falling off the plant soon after (Josselyn and Mathieson 1978). The second means of production comes from Ascophyllum's epidermal tissue which is shed and prevents any biofouled surfaces from affecting the rest of the thallus (Halat *et al*. 2020). This process of epidermal shedding adds 10% of *Ascophyllum*'s unshed vegetative biomass over again into the ecosystem (Halat *et al*. 2015, Garbary *et al*. 2017).

Biochemistry

Commercial interests in *Ascophyllum* developed around its traditional use as a soil supplement. *Ascophyllum* has been used as fertilizer in Ireland since the eighteenth century and in Scotland since the Iron Age (Guiry and Morrison 2013, Barbar 2003). *Ascophyllum* is rich in potassium when compared with cow manure. Raw unprocessed *Ascophyllum* fronds make an excellent fertilizer for poor quality soil (Pereira *et al*. 2020). *Ascophyllum* is similarly rich in plant growth regulators, such as cytokinins, gibberellins, and indoles, as well as chelated compounds that make micronutrients in the soil more readily available for plants (Senn 1987). Many commercial extracts from *Ascophyllum* have been developed that improve the growth and quality of specific human food crops (Senn 1987, Pereira *et al*. 2020). *Ascophyllum* thalli are composed of 20% to 29% alginic acid, the precursor for alginates (McHugh 2003). Industrial food manufacturers value sulfated polysaccharides (e.g, alginates, agar, carrageenan) found in

Ascophyllum and other seaweeds for their properties as gelling and thickening agents. *Ascophyllum* can also be used as animal feed, either raw or in manufactured meal, as the seaweed also contains vitamins and trace elements that elevate growth and productivity in livestock (Pereira *et al*. 2020).

COMMERCIAL HARVEST IN NOVA SCOTIA

History of Harvesting

Fertilizer production from *Ascophyllum* began in eighteenth-century Ireland (Guiry and Morrison 2013). Widespread commercial harvesting of *Ascophyllum* began in Nova Scotia in 1959, primarily in southwestern Nova Scotia and along the Bay of Fundy (Chopin and Ugarte 2006). From 1959 to 1985, annual landings of harvested *Ascophyllum* were under 10,000 wet tons of biomass. This only changed after the introduction of Norwegian mechanical suction cutter technology, enabling annual landings of *Ascophyllum* to increase to up to 30,000 wet tons (Chopin and Ugarte 2006).

This increase in landings drew additional commercial *Ascophyllum* enterprises to Nova Scotia. The resulting intensification of *Ascophyllum* harvesting led to exploitation of widening expanses along the Nova Scotian coastline. During this period, the Nova Scotian government provided little active regulation for this resource, leaving supervision of the *Ascophyllum* stocks in the hands of industry. Overharvesting became a major concern due to the lack of centralized recordkeeping. Observers noted visible degradation of populations especially in so-called “open areas” where anyone could harvest *Ascophyllum*. In 1993, industrial players in Nova Scotia reverted to hand harvesting methods and established a quota system, capping maximum landings from any given *Ascophyllum* bed in Nova Scotia (Chopin and Ugarte 2006). This system persists across Nova Scotia today. Fisheries and Oceans Canada (DFO) evaluated the current stocks and the harvesting system in 2013, and made several recommendations for improving industrial harvest management (Vandermeulen 2013). The extent to which industry, commercial harvesters, and provincial authorities have implemented these recommendations remains unclear.

Management of the Shore

Fisheries and Oceans Canada outlines the provincial limits on harvesting of *Ascophyllum* under Section 71 of the Fisheries and Coastal Resources Act. Features of the act include limits on the amount of holdfast that may be harvested–15% of the total landing–and the minimum amount of thallus that must be left above the holdfast, approximately 127 mm (Government of Nova Scotia, "Rock Weed Harvesting Regulations – Fisheries and Coastal Resources Act (Nova Scotia)" 2017). As of 2013, no areas within the available plots leased for harvest of *Ascophyllum* have been closed permanently (DFO 2013). *Ascophyllum* harvesting leases span nearly the entire length of Nova Scotia's Atlantic shoreline, but active harvesting primarily occurs from the southern end of the province into St. Mary's Bay and in the Annapolis Basin. Acadian Seaplants Limited (herein called ASL) holds 14 of the 22 rockweed leases currently available in Nova Scotia, totaling 327,728.42 hectares, or approximately two thirds of the leases by area. The remaining leases, totaling 155,748.30 hectares, are held by two additional companies and one private individual (Communications Nova Scotia 2014).

Large scale commercial harvesting also occurs in the United States, with significant activity in Maine since the 1970s (Totten 2019). The Maine Department of Marine Resources sets criteria and limits on *Ascophyllum* harvesting in Maine, including a minimum 16" cutting height, maximum harvest rates, and closed areas (DMR 2014). ASL established operations in Maine in 1999 and capped at harvesting to a maximum of 17% of the standing *Ascophyllum* biomass within their areas of operation in the state (Totten 2019). This is the same harvesting limit as in New Brunswick (Ugarte and Sharp 2001). In contrast, Nova Scotia allows for removal of up to 25% of available biomass (Vandermeulen 2013).

However, a recent court case, *Ross v. Acadian Seaplants, Ltd.,* reduces ASL and other harvesters' ability to collect *Ascophyllum* in the intertidal zone. The Maine court ruled that rockweed and associated harvesting rights are held by the "adjacent upland landowner" (Totten 2019) from the intertidal *Ascophyllum* bed. In Canada, by contrast, private property rights end at the top of the intertidal zone. Analysts suggest that the ruling may lead to withdrawal by ASL from the Maine rockweed harvesting industry (Reiter *et al*. 2020). The loss of accessible harvests in Maine's intertidal zones due to

Ross v. Acadian Seaplants, Ltd. may lead to increased exploitation of zones along Nova Scotian shores in the future.

Rakes and Boats

The manner of *Ascophyllum* harvesting represents a key issue for future conversations about its management. While in other jurisdictions commercial harvesters employ mechanical harvesting boats, in Nova Scotia *Ascophyllum* is only harvested manually with a cutting rake designed specifically for rockweed collection (DMR 2014). This cutting rake is “a 3m pole… equipped with sharp tooth-shaped blades held in a rake head protected by three guides” (Ugarte *et al*. 2006). The design of the rake’s guides are meant to prevent *Ascophyllum* from being cut too close to the holdfast, as per Nova Scotian regulations (Government of Nova Scotia, “Rock Weed Harvesting Regulations – Fisheries and Coastal Resources Act (Nova Scotia)” 2017). This design remains in use among harvesters in Nova Scotia as of 2020, though harvesters removed the central guide from most rakes in common use. There appears to be no surviving documentation that details when or why the rake design was changed. However, conversations with harvesters indicated that the middle guide caused greater entanglement of the seaweed frond on the rake, and thus slowed them down during harvesting.

In New Brunswick, ASL manufactures the rakes for harvesters, but there are no regulations in place regarding the rake’s design, only that harvesting must be by hand and follow existing restrictions with respect to total biomass removal and cutting height.

Informal interviews held with harvesters in Yarmouth County in August, 2020, provided more data for understanding the shore-level economic impacts of *Ascophyllum* harvesting. Harvesters selling to ASL earned 55 CAD per ton of *Ascophyllum* in 2020. Each harvester deposits their haul into a blue 10-tonne box which is collected by ASL when full. The boats themselves can contain up to 5 tons of rockweed when they return to the docks. Harvesters report that many boats go out more than once in a single tide. At Wedgeport, NS, five of these boats were spotted from the shore on August 21, 2020, at 8:30 am, only three days after this portion of shore was opened for harvesting by ASL. Harvesting leases remain open until they meet the 25% threshold of biomass in that zone, at which point ASL closes the area and opens another.

In theory, this rolling season allows for consistent harvesting over longer periods of the year without over-harvesting any individual bed. Harvesters report that with two workers, two round trips are required to fill a standard box for ASL, taking approximately five hours to complete.

The manual method of *Ascophyllum* harvesting currently employed in Nova Scotia is more laborious and less efficient than mechanical harvesting (DMR 2014). Harvesters therefore focus on denser areas of *Ascophyllum* growth to maximize their catch per unit effort (CPUE), instead of harvesting evenly across available beds (DMR 2014). This results in uneven cutting frequency and density across *Ascophyllum* beds. These inefficiencies, in turn, may currently be leading to inefficient and irregular renewal of *Ascophyllum*.

Biological and Ecological Changes due to Harvesting

The removal of *Ascophyllum* biomass from the coastal environment impacts the intertidal ecosystem in various ways. Harvesting results in a change in morphology for *Ascophyllum* plants themselves: fronds and branches become shorter and denser, more akin to a bush in structure than an underwater tree (Ugarte *et al*. 2006). Such reactions alter the structural complexity of the *Ascophyllum* beds; while in isolation the effects of these changes might appear negligible, uncut stands of *Ascophyllum* nearby suggest that there is a significant impact as a result of commercial harvesting. Simulated harvesting studies show an unrecoverable decline of species richness, and many species that depend on *Ascophyllum* habitat decline in local abundance after harvesting (Seeley and Schlesinger 2012).

Estimates of biomass removal during harvesting indicate a need for further information and investigation. Industrial sources maintain claims that removal of up to 25% of harvestable *Ascophyllum* biomass from their ecosystem allows for consistent maintenance of available rockweed stocks (Vandermeulen 2013). This number does not account for different subsets of biomass, such as the removal of reproductive tissue or epidermal shedding. Accounting for losses of underdeveloped reproductive tissues removed early in the harvest season, epidermal shedding, and fronds lost to wave action has a significant impact. Studies have estimated that *Ascophyllum* contributes up to 170% of its vegetative weight in shed detrital biomass

(Garbary *et al*. 2021b, in preparation). However, industrial sources contest this claim (Ugarte *et al*. 2017).

The Responsibilities of Industry and the Provincial Government

There is great benefit for industry to take a proactive approach to management and management science, as there is a financial motivation for maintaining the *Ascophyllum* stocks over the long term, and in avoiding a decline in stock as happened in the Irish Moss (*Chrondrus crispus*) industry (Chopin and Ugarte 2006, Vandermeulen 2013). However, there is some evidence that the aims of industry, the province, and coastal ecologists may not be as aligned. In a rebuttal to a new estimate of detrital biomass loss to harvesting, industry ecologists allude to fear that the present harvesting regulations are “to the detriment of the *Ascophyllum* harvesting industry on both sides of the Atlantic, which currently provides considerable employment in areas where jobs are in short supply” (Halat *et al*. 2015, Ugarte *et al*. 2017).

The value of the industry overall is difficult to determine. One can estimate total pay to harvesters based on overall landings and the prices reported by harvesters, but this does not account for rockweed as a value-added product. In Maine, the *Ascophyllum* industry has been reportedly valued at $20 million USD, but no such assessment exists for the Nova Scotian industry, which harvested four times the biomass collected in Maine prior to the *Ross v. Acadian Seaplants, Limited* law case (Willick 2017). Given that the global seaweed industry is expected to be worth $30.2 billion USD by 2025 (Anon. 2020, “Seaweed Cultivation Market by Type, Method of Harvesting, Form, Application And Region – Global Forecast to 2025,”), the sustainability of a largely self-managed industry with limited provincial oversight and cooperation should be of concern.

In addition, one wonders about the state of communication between the scientists tasked with monitoring the rockweed stocks and the harvesters actually doing the collections. The large body of literature on *Ascophyllum* commonly agrees that the seaweed grows no more than 15 centimetres per year (Hill and White 2008). However, conversations with harvesters indicated a general impression of much faster growth, with some decreeing that rockweed could recover a meter of length in a year (personal communications, 2020). With this impression amongst the harvesters, will appropriate care be taken with respect to conservation by those operating the harvesting boats? Unlike the situation in commercial wild-catch fin-fisheries, there are no government observers stationed on the small rockweed harvesting boats or at the docks when they return, to confirm these findings.

The Composition of the Fucoid Zone

Another threat arises in the *Ascophyllum* zone, irrespective of the harvesting. *Fucus serratus* is an invasive species of brown alga from the same family as *Ascophyllum*. It has been expanding its foothold in the province since the 19th century (Brawley *et al*. 2009). Recent work indicates that *Fucus serratus* is newly present on Nova Scotia's South Shore, both in the traditional subtidal and intertidal zone, moving into *Ascophyllum* harvest beds (Garbary *et al*. 2021, in press). The spread of this species is likely enhanced by warming surface ocean temperatures so that it now occupies a new portion of the shore (Filbee-Dexter *et al*. 2016). The growing prevalence of the species is of immediate concern to industry, as it looks likely to crowd out and replace *Ascophyllum* at the bottom of the shore (Garbary *et al*. 2021b, in press).

CONCLUSIONS

Ascophyllum nodosum is an ecologically and commercially important seaweed in Nova Scotia. The exploitation of this resource creates economic opportunities and brings industry to the province. However, the sustainability of the harvesting industry as it currently stands is in question. There are pressing questions about the impact of harvesting on *Ascophyllum* and its intertidal community that require clarification. To keep the *Ascophyllum* harvest sustainable, adjustments may have to be made by industry in the near future.

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REFERENCES

Åberg, P. (1992). A demographic study of two populations of the seaweed *Ascophyllum nodosum. Ecology* 73(4): 1473-1487.

Anon. (2020). Seaweed Cultivation Market by Type, Method of Harvesting, Form, Application And Region – Global Forecast to 2025. https://www.reportlinker.com/p03833615/Commercial-Seaweeds-Market-by-Type-Form-Application-and-by-Region-Global-Forecasts-to.html?utm_source=GNW (Accessed 2.19.21)

Baardseth, E. (1970). Synopsis of biological data on knobbed wrack, *Ascophyllum nodosum* (Linnaeus) Le Jolis. FAO Fisheries Synopsis No. 38, Rev. 1. Food and Agriculture Organization of the United Nations, Rome. 49 p.

Barber, J. (2003). Bronze Age farms and Iron Age farm mounds of the Outer Hebrides. *Scottish Archaeological Internet Reports 3*. 343 p.

Brawley, S.H., Coyer, J.A., Blakeslee, A.M.H., Hoarau, G., Johnson, L.E., Byers, J.E., Stam, W.T. & Olsen, J.L. (2009). Historical invasions of the intertidal zone of Atlantic North America associated with distinctive patterns of trade and emigration. *Proceedings of the National Academy of Sciences USA* 106(20): 8239-8244.

Chopin, T. & Ugarte, R. (2006). The Seaweed Resources of Eastern Canada. Mimeo, pdf. University of New Brunswick, Saint John, NB. pp. 1-46.

Clement, K. (2008). Air bladder repair in the intertidal seaweed, *Ascophyllum nodosum* (Fucales, Phaeophyceae). BSc (Honours) paper, Saint Francis Xavier University, Antigonish, NS.

Communications Nova Scotia. (2014). Site mapping tool. Available from https://novascotia.ca/fish/aquaculture/site-mapping-tool/ (Accessed 15 February 2021)

DFO. (2013). Assessment of Information on Irish Moss, Rockweed, and Kelp Harvests in Nova Scotia. Fisheries and Oceans Canada, Science, Maritimes Region, Canadian Science Advisory Secretariat, Science Advisory Report 2013/004, March 2013. 17 p.

DMR. (2014). Fishery management plan for rockweed (*Ascophyllum nodosum*). Department of Marine Resources, Maine. Available from https://www.maine.gov/dmr/science-research/species/rockweed/documents/DMRRockweedFMPJan2014.pdf (Accessed 14 February 2021)

Filbee-Dexter, K., Feehan, C. & Scheibling, R. (2016). Large-scale degradation of a kelp ecosystem in an ocean warming hotspot. *Marine Ecology Progress Series* 543: 141-152.

Fritsch, F.E. (1945). The Structure and Reproduction of the Algae. Vols. I and II. Cambridge University Press, Cambridge, England. 791 p., 939 p.

Garbary, D.J. (2017). Harvesting *Ascophyllum nodosum* (Phaeophyceae) reduces the abundance of its host-specific epiphyte *Vertebrata lanosa* (Rhodophyta). *Botanica Marina* 60(3): 297-301.

Garbary, D.J., Fass, M.P. & Vandermeulen, H. (2021a). A new pattern of seaweed zonation in the northwestern Atlantic Ocean based on invasive *Fucus serratus* (Fucaceae, Phaeophyceae). In preparation.

Garbary, D.J., Galway, M.E. & Halat, L. (2017). Response to Ugarte *et al.*: Ascophyllum (Phaeophyceae) annually contributes over 100% of its vegetative biomass to detritus. *Phycologia* 56(1): 116-118.

Garbary, D.J., Grund, D.W. & McLachlan, J. (1980). Branching patterns and life history stages in Ceramium rubrum (Huds.) *C. Ag. Nova Hedwigia* 33: 249-260.

Garbary, D.J., Kennedy, A., MacNeil, K. & Kang, E.J. (2021b). Reproductive allocation of Ascophyllum nodosum (Fucaceae, Phaeophyceae) in Nova Scotia, Canada. Manuscript in preparation.

Government of Nova Scotia. (2017). Rock Weed Harvesting Regulations – Fisheries and Coastal Resources Act (Nova Scotia). December 10. Available from https://www.novascotia.ca/just/regulations/regs/fcrweed.htm (Accessed 18 February 2021)

Guiry, M.D. & Morrison, L. (2013). The sustainable harvesting of Ascophyllum nodosum (Fucaceae, Phaeophyceae) in Ireland, with notes on the collection and use of some other brown algae. *Journal of Applied Phycology* 25(6): 1823-1830.

Halat, L., Galway, M.E. & Garbary, D.J. (2020). Cell wall structural changes lead to separation and shedding of biofouled epidermal cell wall layers by the brown alga Ascophyllum nodosum. *Protoplasma* 5: 1319-1331.

Halat, L., Galway, M.E., Gitto, S. & Garbary, D.J. (2015). Epidermal shedding in Ascophyllum nodosum (Phaeophyceae): seasonality, productivity and relationship to harvesting. *Phycologia* 54(6): 599-608.

Hill, J.M. & White, N. (2008). Knotted wrack (Ascophyllum nodosum). Marine Life Information Network: Biology and Sensitivity Key Information Reviews. MarLIN – Marine Life Information Network.

Josselyn, M.N. & Mathieson, A.C. (1978). Contribution of receptacles from the fucoid Ascophyllum nodosum to the detrital pool of a north temperate estuary. *Estuaries* 1(4): 258-261.

Kay, L., Eddy, T.D., Schmidt, A.L. & Lotze, H.K. (2016). Regional differences and linkage between canopy structure and community composition of rockweed habitats in Atlantic Canada. *Marine Biology* 163: 251. doi:10.1007/s00227-016-3027-3

Mathieson, A.C. & Dawes, C.J. (2017). Seaweeds of the Northwest Atlantic. University of Massachusetts Press, Amherst and Boston, MA. 816 p.

McHugh, D.J. (2003). A guide to the seaweed industry. FAO Fisheries Technical Paper 441. Food and Agriculture Organization of the United Nations, Rome. 118 p.

Pereira, L., Morrison, L., Shukla, P.S. & Critchley, A.T. (2020). A concise review of the brown macroalga, Ascophyllum nodosum (Linnaeus) Le Jolis. *Journal of Applied Phycology* 32: 3561-3584.

Reiter, S., Post, D., Wedding, L. & Strong, A. (2020). The future of the public trust: the muddied waters of rockweed management in Maine. *Ocean and Coastal Law Journal* 25(2): 235.

Seeley, R.H. & Schlesinger, W.H. (2012). Sustainable seaweed cutting? The rockweed (Ascophyllum nodosum) industry of Maine and the Maritime Provinces. *Annals of the New York Academy of Science* 1249(1): 84-103.

Senn, T.L. (1987). Seaweed and Plant Growth. Clemson University, Clemson, South Carolina, USA. 181 p.

Sharp, G. (1987). Ascophyllum nodosum and its harvesting in Eastern Canada. In Case studies of seven commercial seaweed resources. Doty, M.S., Caddy, J.F. and Santelices, B. (eds.). FAO Fisheries Technical Paper 281. Food and Agriculture Organization of the United Nations, Rome. 311 p.

Totten, R.P. (2019). Defining fishing, the slippery seaweed slope, Ross v. Acadian Seaplants Ltd. *Ocean and Coastal Law Journal* 24(2/4): 178-218.

Ugarte, R.A., Critchley, A., Serdynska, A.R. & Deveau, J.P. (2009). Changes in composition of rockweed (Ascophyllum nodosum) beds due to possible recent increase in sea temperature in Eastern Canada. *Journal of Applied Phycology* 21(5): 591-598.

Ugarte, R.A., Lauzon-Guay, J.-S. & Critchley, A.T. (2017). Comments on Halat L., Galway M.E., Gitto S. & Garbary D.J. (2015). Epidermal shedding in Ascophyllum nodosum (Phaeophyceae): seasonality, productivity and relationship to harvesting. *Phycologia* 54(6): 599-608.

Ugarte, R.A. & Sharp, G. (2001). A new approach to seaweed management in Eastern Canada: The case of Ascophyllum nodosum. *Cahiers de Biologie Marine* 42(1): 63-70.

Ugarte, R.A., Sharp, G. & Moore, B. (2006). Changes in the Brown Seaweed Ascophyllum nodosum (L.) Le Jol. Plant Morphology and Biomass Produced by Cutter Rake Harvests in Southern New Brunswick, Canada. *Journal of Applied Phycology* 18**:** 351. https://doi.org/10.1007/s10811-006-9044-8

Vandermeulen, H. (2013). Information to support assessment of stock status of commercially harvested species of marine plants in Nova Scotia: Irish moss, rockweed and kelp. Unpublished Research Document, Fisheries and Oceans Canada, Maritimes Region, Bedford Institute of Oceanography, Dartmouth, NS.

Willick, F. (2017). Court battles, conservation and a cornered market: rockweed industry in state of flux. Local Xpress. https://www.localxpress.ca/localnews/