Rockweed in Maine's Intertidal Zone

Working Towards a Sustainable Harvest

Pictured: *Ascophyllum nodosum* at high tide (Source: *Hakai Magazine, 2018*)

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Executive Summary

Ascophyllum nodosum, colloquially called Rockweed, is a brown macroalgae that has been commercially harvested along Maine's intertidal flats since the 1970s. Maine harvest has increased twofold in the past decade, fueling conflicts between harvesters and owners of Maine's scenic coastline. In March, the Maine Supreme Court ruled in *Ross v. Acadian Seaplants* that rockweed in the intertidal is the property of the upland owner, and harvesters must ask for landowner permission before harvesting on their flats. This ruling left both sides far from satisfied, and took away power from Maine's Department of Marine Resource to implement coastwide sector management. Confusion abounds between landowners about how their decision can be properly enforced, between fisheries about their company's future, and between ecologists about what constitutes a sustainable harvest. I recommend *Ross* be repealed, and a new working group be implemented to create an updated *Ascophyllum* Fisheries Management Plan, replete with sector area-based management, height and biomass restrictions, and conservation areas, for centralized government of this resource, not private ownership, is essential to ensure its stability in upcoming decades.

Context

Heralded by some ecologists as the "old growth forest" of the sea, *Ascophyllum* is an essential ecosystem engineer upon which more than 150 marine species depend" [1]. *Ascophyllum* reduces physical stresses (such as drying, summer heat, high light, or wave exposure) for the affiliated intertidal communities [2,3,4,5]. Though many species benefit indirectly from rockweed, most directly depend on its presence to survive; some, such as epiphytes and larvae, even affix

themselves directly to the surface of the algae [6]. In addition to providing a vital habitat, rockweed sequesters carbon and nitrogen, provides energy to the food web by feeding grazers, and helps nutrients stay distributed throughout the water column [7, 8]. With a habitat ranging from Portugal to Greenland to the New England coast, its influence on both ecosystem and economy is global and long-swaying. *Ascophyllum* is the dominant alga in the North Atlantic, and makes up more than 95% of the algal makeup in Maine's coast [9]. *Ascophyllum* evolved in stressful and disruptive habitats, survived multiple glacial-interglacial cycles over tens of thousands of years [10]. Its long life-span, high fecundity, and high within-population diversity has safeguarded the species from extinction over tens of thousands of years of glacial-interglacial cycles [11].

Pictured: Distribution of *Ascophyllum nodosum* (source: *Wikipedia*)

Localized in Maine, *Ascophyllum* has been documented as early as 1946, and when commercial harvest began in the 1970s, commercial harvest was already documented in Iceland, Norway, the British Isles, and Eastern Canada, for use in the fertilizer and seafood packing material industry [12]. In Maine today, it is harvested for many uses, including as packing material,

nutritional supplements, agricultural products, and fertilizer[13]. The Ocean Organics and Acadian Seaplants, two major harvesters in Maine, are founded upon the production of bioextract, a kind of fertilizer that has been shown to increase the uptake of fertilizer and thus increase the bounty of the crop[14]. The positive ecological effects of *Ascophyllum* don't just end there -- it is also being studied for its effects on reducing methane emissions of cows when the product is added to their feed[15]. An increased demand for these products has coincided with an expansion of the market; the 2018 landings report of 22.3 million pounds was almost twice the 12.7 million pounds reported in the 2008 harvest[16]. To date, there are 154 licensed seaweed harvesters in Maine, with a landings profit of $820,850 in 2018[17].

HISTORICAL MAINE ROCKWEED LANDINGS

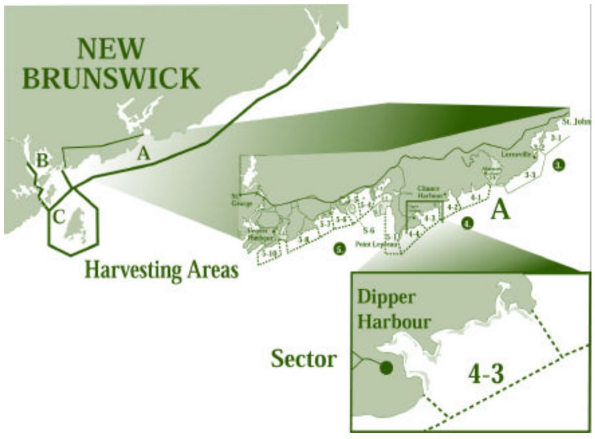
YEAR	SPECIES	LANDED POUNDS	LIVE POUNDS	unds (Millior	VALUE	lue (Millior
2001	ROCKWEED	4,760,078	4,760,078	4.76	$84,138	$0.08
2002	ROCKWEED	5,669,067	5,669,067	5.67	$99,681	$0.10
2003	ROCKWEED	3,276,511	3,276,511	3.28	$57,339	$0.06
2004	ROCKWEED	3,032,871	3,032,871	3.03	$53,045	$0.05
2005	ROCKWEED	4,280,734	4,280,734	4.28	$74,913	$0.07
2006	ROCKWEED	7,124,677	7,124,677	7.12	$142,494	$0.14
2007	ROCKWEED	6,775,612	6,775,612	6.78	$135,512	$0.14
2008	ROCKWEED	11,654,227	11,654,227	11.65	$233,085	$0.23
2009	ROCKWEED	11,090,274	11,090,274	11.09	$332,708	$0.33
2010	ROCKWEED	12,676,252	12,676,252	12.68	$380,288	$0.38
2011	ROCKWEED	14,735,164	14,735,164	14.74	$442,055	$0.44
2012	ROCKWEED	14,625,667	14,625,667	14.63	$438,770	$0.44
2013	ROCKWEED	16,786,501	16,786,501	16.79	$503,595	$0.50
2014	ROCKWEED	16,282,440	16,282,440	16.28	$561,824	$0.56
2015	ROCKWEED	14,981,702	14,981,702	14.98	$515,916	$0.52
2016	ROCKWEED	17,367,229	17,367,229	17.37	$557,490	$0.56
2017	ROCKWEED	20,355,995	20,355,995	20.36	$657,508	$0.66
2018	ROCKWEED	22,303,202	22,303,202	22.30	$820,846	$0.82

*2018 data are prelimianry and subject to change without notice.
Last updated 2/19/19

Pictured: Historical landings of *Ascophyllum nodosum.* (source: *Department of Marine Resources*).

Pertinent management of this resource began in the 1990s, when harvesters expressed interest in expanding from the long-exploited area of Nova Scotia to virgin New Brunswick[18]. In 1995, the DFO created a new pilot program that included gear restrictions, a maximum

exploitation rate of 17%, a minimum cutting height, gear restrictions, and protected areas, such as that for shorebirds [19]. In 2000 the DMR mandated a landings report and a maximum cutting height for the resource of 16," and a measure to preserve rockweed's lowest lateral branches [20]. In 2009, the Cobscook Bay Management Area was created, a virtual "carbon copy" of the New Brunswick management strategy, replete with sector area-based management, and restrictions on cut height, and a 17% biomass uptake restriction [21, 22]. In 2014, the DMR produced the Fishery Management Plan for Rockweed [23]. Its plan, boiled down, was to extend the Cobscook Bay Rockweed Management Area down the entire Maine coast [24]. The Rockweed Working Group was created in addendum to the FMP to review and discuss a profile for no-cut conservation areas, to be added to the management plan [25].



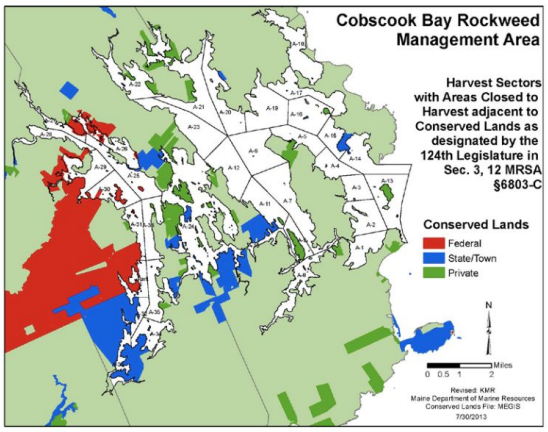


Figure 3. 2013 Cobscook Bay Rockweed Management Area sectors.

Pictured: New Brunswick Rockweed Management Strategy & Cobscook Bay Rockweed Management Area (Sources: Ugarte et al., 2001; DFP, 2014)

Harvest of *Ascophyllum* in Maine is completed either by hand or via mechanical harvester [26]. Hand-harvesters cut either by plunging a rake into the water or by cutting the fronds with a knife [27]. Because they are labor-intensive and inefficient, hand-harvest focuses on dense beds in a non-uniform manner [28]. That fact, combined with the inherent environmental variability of the intertidal, created a harvest pattern that is non-uniform and well-above the 16" mark [29].

Mechanical harvesters are typically flat-bottomed, 20-foot long boats [30]. Fronds cut via the cutting head at the vessel's bow travel through a hose and directly into net bags [31]. Similar to handrakes, the cutting-head of the harvester achieved a cut that is non-uniform and above 16" [32]. In fact, personal observation from Phillippi et al, 2014, has found that commercially harvested fronds average at 60cm, or 23.6 inches, a full 7.3 inches above the required cutting height [33].

The benefits of sector-based management is twofold. Ecologically, it allows for fragile areas to be protected and resilient areas to be optimized [34]. Economically, it negates competition and instills economic security in harvesters [35]. However, the DMR stalled continued action on both the FMP and the Working Group when Cobscook Bay landowner and environmental activist Kenneth Ross sued Acadian Seaplants, Ltd for harvesting on his flats [36]. In accordance with the largely antiquated Colonial Ordinance of 1647, Ross argued that he had purveyance over the intertidal zone, and harvesting rockweed could not be considered under the public easement of "fishing, fowling, and navigation" [37,38]. This past March, the Maine Supreme Court ruled in favor of the homeowners [39]. Now, harvesters must ask permission from coastal landowners to harvest rockweed from the intertidal zone [40].

In the months following *Ross*, landowners, harvesters, ecologists and lawmakers on both sides of the debate are far from satisfied [41]. The question of enforcement has become all-the-more sticky with the lack of a clear-cut regulatory enforcement for attaining landowner permission [42]. Discord has arisen between ecologists as well, as some have expressed concern over whether the current harvesting regimes will continue to be sustainable as the intensity of harvest increases [43]. Finally, the very foundation of the ruling (i.e. the dismissal of Maine's claim of ownership of the resource) has been called into question, and the upcoming legislative session may see more

concentrated efforts to topple *Ross*[44]. The state argues that under 1 MRSA 2(2-A), they own "all living resources of the sea"[45]. But in the interim, there exists an urgent need to instate measures to streamline enforcement, homeowner communication, and harvester training.

Critique 1: *State Conservation in the wake of Ross*

The sweeping conclusion among most harvesters and ecologists is that the centralized area-based management is the best way to properly conserve *Ascophyllum*[46]. Though the DMR still has some legislative authority over the resource (such as monitoring cut height and establishing conservation areas), area-based management is incongruent with the *Ross* ruling[47]. The Department of Marine Resources is planning to submit a bill in the upcoming legislative session that would repeal the Cobscook Bay Rockweed Management Area, Maine's version of a pilot program for sector-based area management[48]. Gordon Smith, the lawyer for Kenneth and Carl Ross, believes that the law doesn't have to be repealed; rather, it could be amended and extended down the entire coast[49]. Harvesters could submit permission agreements when they submit sector plans[50]. In addition, he argues, property owners could sell rockweed to other interested harvesters[51].

Critique 2: *Private Conservation in the wake of Ross*

In 2015, an amicus brief filed in support of landowners stated that private ownership was the most effective way to conserve *Ascophyllum*[52]. Property owners, the authors argue, are better judges on sustainable harvest than harvesters, and have more to gain from conservation[53]. Conversely, harvesting companies and the DMR believe that "conservation is undoubtedly best

achieved through buy-in to to regulations that conserve species" [54]. Seaver adds to Mendelson's argument, saying that no one is more concerned about conservation than harvesters [55]. If the ecosystem declines his business will, as well [56]. In fact, Seaver argues, putting the resource in the hands of the private landowners could be *harmful* to the ecosystem [57]. There aren't just those who "don't want rockweed harvested and those who don't care," but there's also those want to profit from harvest [58]. "At some point there will be a time where landowners sell to the highest bidder" [59].

Landowners restrict harvest based on flawed logic, argues Raul of *Acadian Seaplants* [60]. Some landowners restrict harvest because it appears as if harvesters return to the same region every year, and research has shown that cutting the same clumps each year will reduce biomass [61,62]. However, Seaver claims that even if it looks like harvesters are returning to the same spot each year, they are actually cutting the fronds that have grown in light of the larger fronds being shorn the previous year [63]. If they can help it, though, harvesters naturally avoid returning to exactly the same area, for it is much easier to harvest a dense area of *Ascophyllum* [64]. Because of this confusion, a paradox of protection has arisen. Harvesters argue that private ownership of rockweed, in an attempt to protect it, is forcing harvesters to unsustainably work in more concentrated areas.

Critique 3: *Enforcement in the wake of Ross*

In the months following *Ross,* enforcement of the decision has become complicated and contentious. Some homeowners have witnessed harvesters cutting on their flats without asking permission [65]. However, most of these complaints never reach regulatory authority [66]. In fact, the

DMR received under a dozen such complaints from landowners along the entire coast in 2019 [67]. Those they have received have been resolved without a citation or summons, and the DMR doubts they will use those measures in the future [68]. Kenneth Ross, speaking for other upland owners, believes a more standardized method of enforcement -- including a written agreement and more strict enforcement -- is necessary to protect the resource [69]. But for the DMR, writing summons is not only a significant resource drain, but also a challenge to take to court [70]. For the department to discipline a harvester for a violation, a landowner has to present a deed proving ownership of the intertidal, and provide evidence that harvesting occurred in their property [71]. Many deeds are antiquated and unclear. For example, if landowners own property on a cove, there exists a good chance that the upland owner's intertidal deeds will overlap [72].

Critique 4: *Economics in the wake of Ross*

The March decision was "basically a death sentence for a lot of companies," said Bonnie Tobey, operations manager of Source Inc [73]. Source has lost half the area it used to harvest around Harpswell [74]. Their processing plant is down to one shift, and its two harvester work half of their normal hours [75]. Though almost 80 percent of the people *Acadian* has contacted have okayed harvest on their flats, the Maine harvest of the company is down by 50 percent [76,77]. Ocean Organics, a company in Waldoboro, Maine, has not yet felt negative effects from *Ross*, but representatives fear that soon they will experience difficulty receiving a bank loan, a land-grab for landowner permission, and a decline in harvestable areas from murky property records [78]. Finally, they fear that placing the resource in the hands of the public will compromise a statewide management plan that will protect the resource in the long-term [79].

Critique 5: *Understanding in the wake of Ross*

In the past few months, scientists have taken polarized opinions regarding the response of *Ascophyllum* to different management regimes [80]. Some landowners and ecologists are alarmed at the twofold increase in landings over the past decade, especially since the 2018 landings are reported to be a whopping 22.3 million pounds [81,82]. However, harvesters argue that this growth rate in the industry is far from exponential; rather, it has been growing at a steady rate of 13% per year [83]. Furthermore, most of that increase is due to harvest from *Acadian Seaplants;* Seaver would wager that the Maine-based companies have only increased their harvest by 20% in the past 10 years [84]. Finally, exologists such as Susan Brawley say that gathering 2 percent of landings is well within the maximum sustainable yield, for *Ascophyllum* is very resilient, and "evolved in stressful, disruptive habitats" [85].

In addition, natural forces, such as scraping from ice or wave-action separate about 40 percent of the upper canopy each year [86]. In fact, Ugarte et al (2011) found that the amount of biomass detached each year by coastal storms is 21 times higher than that detached by the annual commercial harvest [87]. Other conservationists, such as Kenneth Ross, argue that the amount 'harvested' by nature each year is beside the point, because a two percent harvest *in addition to* a 40 percent one could tip the scale to an ecosystem decline [88]. Ugarte points out that when harvesters uptake the highest branches, that is *included* in the 40% that is taken by nature [89]. In this framework, as long as harvest is managed correctly, a slight increase in the industry in the upcoming decades is unlikely to cause a trophic cascade.

Recommendation 1: *Repeal Ross v. Acadian Seaplants*

There are both legal and scientific bases to repeal the March ruling of *Ross v. Acadian Seaplants*. First, there exists much public confusion about whether rockweed is a plant, and whether that discrepancy would have held ground in a court of law [90]. *Ascophyllum* is certainly not a plant, and that certainly would have strengthened the *Acadian Seaplants'* argument if they were to have brought up that issue in the midst of the court's proceedings. Both sides of *Ross* agreed *Ascophyllum* was a plant, and that distinction was critical in the March proceedings [91]. After all, the appelates are called Acadian Sea*plants*. Even the DMR's Fisheries Management Plan acknowledged that *Ascopohyllum* is a plant [92]. Since the court case, many editorials have been published highlighting the fact that the case was based on "faulty science" [93]. Though *Ross* ruled that "Rockweed is biologically dissimilar from fish, lobster, clams, or oysters," ecologists argue that using that same string of logic, a human is genetically closer to a mushroom *Ascophyllum* is to a plant [94,95]. Instead, it is a member of the kingdom chromista [96].

Acknowledging that rockweed is not a plant would certainly have helped *Acadian Seaplants* is brought up before the case was decided, but this semantic difference should not be the main focus in the as policymakers prepare for the upcoming legislative session. When the court ruled that *Ascophyllum* "is not held in trust by the state for public use," it disregarded the fact that, plant or not, *Ascophyllum* is a living resource of the sea [97]. Under 1 M.R.S. 2(2-A), the state "owns and shall control the harvesting of the living resources" [98]. Additionally, "marine resources" is defined by the DMR as "all renewable marine organisms and the entire ecology and habitat supporting these organisms" [99]. Therefore, plant or not, ownership of rockweed should lie with the state. The main reason *Acadian Seaplants* lost was not that semantic difference, but

rather that the court did not consider the DMR to be an indispensable party in the case [100]. Therefore, the argument "was not meaningfully developed in the trial court and is therefore not considered for appellate consideration" [101].

Ross may have dismissed the statute, but it did not dispel the statute. Instead of clearing the air as to where ownership rests, *Ross* has, instead, just caused more confusion. Even harvesting companies don't completely understand who has the last say about ownership. "When you fly higher in this project," commented George Seaver, "you will get to the question of ownership: who really owns the intertidal zone?" [102]. Though the was decided months ago, it is far from closed, and the upcoming legislative may see a completely different answer to that question than apparent today.

Recommendation 2: *Maintain both the 16" minimum cutting height and the lowest lateral branch requirement*

Defense: Even though the question of the proper height for harvest management remains in dispute, the fact remains that some form of cut length protection must remain in place. The 16-inch cut height ensures that some, if not most, of the lateral branches are preserved [103]. When cut to 16" or more, differences between harvested and non-harvested sites can return to equilibrium within two or three years [104, 105, 106, 107, 108]. Some studies have even shown that the biomass regenerates in one year after harvest [109]. When cut shorter that 16", Keser et al. (1981) and Fegley et al. (2001) found that biomass did not even regenerate to 70% of the original in 2-3 years [110, 111]. When the entire holdfast is removed, it takes significantly longer to return to pre-cut biomass [112, 113, 114, 115]. A 2004 study study by Jenkins et. al of full holdfast removal in the British

Isles demonstrated a mere 46% recovery of the organism after 12 years [116]. Although the Fisheries management plan claimed that the lowest lateral branch requirement was a vestigial restriction, I find no reason to dismiss it from the plan[117]. Critics of the 16" cut height claim it is too short to preserve the lowest lateral branches, while proponents argue that a higher cut height would cause an increase in the area harvested [118, 119]. Maintaining the lateral branch is just another protective measure to ensure that enough of the clump is protected to grow back in the future, without having to increase the minimum cut length.

Additional Considerations: Critics of the 16" harvest claim it is regularly broken, while the Department of Marine Resources questions the validity of their argument, claiming their records contradict that claim [120, 121]. In fact, the opposite seems to be true. From first-hand accounts of Phillippi et al. (2014) and George Seaver, both hand-rakes and mechanical harvesters cut *Ascophyllum* in a non-uniform manner that is considerably above the 16" cut height -- between 50-60cm, or about 20-24 inches [122, 123].

Recommendation 3: *Create a new area-based management plan*

1. **Implement a new Rockweed Plan Development Team:** Susan Brawley, one of the leading ecologists in the 2014 PDT suggests that if Ross were to be repealed, the next necessary step is to follow up the 2014 Plan Development Team with a new one [124]. I agree. This working group should consist of a similar cross-section of industry executives, ecologists, and state representatives. To provide a basis for work, a portion of the members should consist of those from the old Plan Development Team, while the

other portion should consist of new members, so that a fresh perspective is maintained on the issue.

2. **Create Sector-Based Area Management:** I believe that the most effective plan in which to preserve the resource is to implement area-based management down the entire Maine coast. A management plan crafted over months by experts in the field is undoubtedly a more effective way to protect the resource. The plan development team would be tasked with dividing the coast into sectors, taking into account the economic and ecological forces driving each region. For example, if one area of the coast is a hub of harvest, it may be subdivided into more sections, so that harvesters would be able to acquire leases to an area that is relatively close to their home base.

   Additional Considerations: Although Gordon Smith proposed that area-based management could be implemented even with the present court ruling, I believe this proposition to be infeasible [125]. Because private allowance of harvest is subjective and ephemeral, it would compromise any statewide area-based management plan. For example, imagine that two harvesters submitted permit applications complete with landowner signatures, and both were assigned a lease of six years. Without warning, a landowner could revoke permission to harvest in one area, and the DMR would have no way of stopping that from happening.

3. **Implement No-Cut areas:** In 2015, Brian Beale, a professor of Marine Ecology at the University of Maine was tasked with providing a literature review on the effects of harvest on affiliated intertidal communities [126]. Although he rejected "the rationale for large closures of the Maine coast that the Rockweed Working Group has discussed," I

still believe it is necessary to implement specific no-harvest areas in light of recent studies [127]. In Holbertson et al (2019), the harvest of rockweed was listed as a potential threat to shore bird populations [128]. For the first few weeks of Eider duckling's lives, they rely on the amphipods that live in the shelter of rockweed's upper branches, and cutting has been proven to disturb their food source, but only (as other ecologists have pointed out) when combined with a steep slope [129, 130]. That is just one of many examples of the ways in which harvest (in specific places at specific times) may damage the affiliated intertidal community.

Unlike the 2014 Management Plan, the new Plan Development Team will be responsible for assessing ecological vulnerability when designating sectors in the management plan. If they deem vulnerability of rockweed or the affiliated intertidal community to be extreme, they reserve the right to close off the area. Seasonal closures will be considered as well, when considering the migration patterns of shorebirds. If a population concentrated in one area every year, that section may be closed off to harvest.

Additional considerations: As will be mentioned later, I also recommend that no-cut zones be established for the express purpose of ecological study (See **Rec. 4)**

4. **Area-Specific Biomass restriction**

Description/Rationale: I recommend that baseline for 17% biomass removal be altered, and that a site-specific biomass restriction be instituted for each area. The fisheries department in New Brunswick created the 17% biomass uptake restriction in their 4-year pilot program in 1995 [131]. It was an upgrade to the previously-established biomass restriction in New Brunswick that with 40-60% biomass removal, a 2-3 year fallow

period must be established [132]. Instead of using a fallow period, the DFO calculated that because biomass turnover averaged at once per 2-3 years, a 17% biomass restriction would be appropriate [133]. In 2009, the Cobscook Bay Management Plan adopted that restriction [134]. The 2014 Fisheries Management Plan set their default management biomass uptake restriction as 17% as well [135]. However, Seeley & Schlessinger (2014) calculated that, in fact, decreased productivity from cutting would cause *Ascophyllum* to regenerate at a slower rate than the new Brunswick fisheries department predicted [136].

The growth rate of Ascophyllum is highly variable along the coast of Maine, New Brunswick and Nova Scotia, with growth rates ranging from 1.3 cm/yr to 20+cm/yr [137]. Biomass regeneration isn't just dependent on location and age, but also hinges on the extent and pattern of branching, and the presence or absence of grazers [138, 139]. All of these confounding variables undoubtedly make it harder to discover an overarching trend in growth rate. This calls for the Department of Marine Resources, while designating harvest sectors, to evaluate the specific growth and ecological vulnerability rate of different areas, and tailor a specific biomass uptake requirement for each sector. For example, if rockweed environmental uptake is significantly higher than the average of 40%, then more strict biomass regulations may be required. Raul Ugarte, the senior ecologist at Acadian Seaplants and the man behind the review of the original plan in which the 17% uptake was implemented, believes that a sector based biomass restriction would be much more effective than a 17% restriction along the entire coast [140].

5. **New Reporting Requirement**

Description/Rationale: The 2014 FMP recommends that sector holders must submit an annual sector report that includes amount removed the previous year, information on ecosystem function and vulnerability, and a general description about where harvesting occurred [141]. I recommend that the new management plan, not only include the aforementioned reports, but also include a specific map detailing where harvest occurred the previous year. I believe that this reporting requirement may be the necessary first step before requiring a kind of rotational harvest system modeled after the present practices of Source, Inc [142]. This harvesting company requires that their harvesters provide detailed maps that show exactly where harvest occurred in the past season [143]. If compiled over 10 years, one can see that each year, the company returned to a different location to allow regeneration of the previously harvested crop [144].

Additional Considerations: The FMP suggests implementing implementing a rotational program in which, if 30% of a region's biomass were to be harvested, it must sit fallow for two years under a crop rotation [145]. However, this plan would be dependent upon streamlining process of harvest reporting, and figuring out how something like this would be enforced. It also requires additional research as to whether significant benefits are ascertained if a fallow period were implemented.

6. **New Training Requirement**

Description/Rationale: In accordance with the 2014 Fisheries Management Plan, I suggest implementing a requirement for a mandatory harvester training program [146]. The FMP did not go into detail about the program specifics, but it suggested including review over statutes, tool maintenance, ecology, and harvester/landowner relations [147]. I believe

that the new PDT should model a harvest program after that of *Acadian Seaplants.* For new harvesters, they pair a new harvester with an experienced harvester for a few weeks [148]. This imbues new harvesters with a basic understanding of how to properly operate the equipment. This is especially important given the fact that both manual and mechanical harvest have the ability to negatively affect *Ascophyllum* populations if not properly utilized [149]. For example, if harvesters learn how to maintain the 16" height requirements and avoid letting the blades become dull, then fewer holdfasts will be taken up with the clumps. Additionally, every year, *Acadian* has a meeting (called Kick-Off), in which they discuss both the ecology of rockweed and the statutes surrounding it [150]. Finally, *Acadian* has an internalized enforcement program, in which harvester receives fewer weekly profits if their internal harvest regulation is broken [151]. This internalized programming is something that the PDT could try to implement in all of the Maine harvesting companies, and it would certainly incentivize harvesters to make sure they were harvesting in an ecologically conscious manner.

Recommendation 4: *Implement a scientific working group and scientific study areas*

Description/rationale: I recommend that, in addition to the new Plan Development Team, a new working group be developed that does yearly literature reviews, informs the Plan Development Team on the ecological vulnerability of different sectors, and establishes and maintains protected *Ascophyllum* study zones. I believe this to be especially needed in recent years, as the effects of climate change on *Ascophyllum* remains largely unstudied and unknown. *Ascophyllum* is a cold-adapted species, and Olsen et al (2010) warns that *Ascophyllum* may decline in light of

warming waters [152]. This is especially important to study in Maine, where waters are warming faster than the rest of the world [153]. Beal (2015) suggested implementing three ¼-½ mile long marine protected zone [154]. He recommended that these zones be used primarily to study rockweed, but also can be used by other scientists to study affiliated intertidal communities [155]. George Seaver (2019) recommended that one such be established in Cundy harbor, in which "we can compare coastal areas that have been harvested systematically for 40 years to those that have been left untouched… to further understand the potential impact of long-term harvesting" [156]. The Department of Marine Resources expressed concern about how funding could be acquired for study areas such as this [157]. Beal recommends that funding could be acquired from sources such as the Seaweed Management Fund, and the Scallop Research Fund [158].

Additional Considerations: I recommend that future studies in these areas focus on the following:

a. Monitoring how natural mortality to harvest mortality changes up and down the coast.
b. How *Ascophyllum* and associated communities respond to warming waters (could include controlled laboratory experiments)
c. Implement an experimental harvest program to test whether a 'crop rotation' program would program would provide significant benefits to intertidal communities up and down the coast
d. Studies on how structural change affects intertidal communities, and how long it takes, on average for *Ascophyllum* to return to its pre-harvest structure.

e. On a more broad level, future studies should shift away from artificial, experimental cutting to studying the effects of tools that harvesters actually use, such as the cutter rake, the knife, and the artificial harvester.

Recommendation 5: Interim Measures to "Adjust to the New Paradigm"

Description/Rationale: "Changes in law take time to go into effect," writes Mendelson, "and we do feel that there will need to be some patience (and education) on the part of the landowners and the harvesting company as well as the harvesting company as everyone seeks to adjust to this new paradigm" [159]. Even if *Ross* were to be repealed, the issues that still exist with harvest today must be addressed. As a significant amount of power over this resource has shifted into the hands of the landowner, I believe it necessary to educate landowners both about both the ecology of rockweed and the extent of their purveyance. In 2013, the Maine Sea Grant, in partnership with the Maine Department of Marine Resources, created a document that provides a succinct and easily digestible overview of ecology, industry, and management of the resource [160]. I believe that the Sea Grant and DMR should also be tasked with creating an updated fact sheet, putting particular emphasis on management in the wake of *Ross.* This sheet should either be mailed to homeowners, and/or put on an easily-accessible digital platform. Second, I recommend crafting a streamlined way in which to establish a harvest agreement between harvesters and landowners. Kenneth Ross is presently working on creating a document that standardizes the permission process. Both harvesters and landowners would have a copy, and the document would be filed with the DMR, as well.

Additional Considerations: I also recommend that the following information be included in the informational packet: not only can the upland property owner reject or allow harvest, but they also have the power to further restrict harvest, if they so choose. They could potentially ask for a more restrictive cutting height, or could allow harvest in one area of their property, but not another [161]. Even so, the only enforcement mechanism they can use for these modifications is to deny future harvest -- they could not call in authorities to enforce their new regulations [162]. Also, because the DMR still retains legislative authority over *Ascophyllum,* landowners wouldn't be able to impose restrictions that rub up against that of the DMR. For example, property owners could not modify harvest on their property to a maximum of 10 inches because that would break the 16" cut height restriction.

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