Review of Existing Literature to Assess Effects of Rockweed Harvest on Marine Habitats and Invertebrates

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As the Rockweed Working Group's ecologist, I was asked by the Department of Marine Resources to review studies assessing effects of rockweed harvest on habitats and invertebrates because of the relevance to the Group's task of understanding these effects and using that information to recommend areas that are closed to commercial harvest.

I reviewed four published and three unpublished works that directly or indirectly examined effects of rockweed harvesting or removal of rockweed on algal habitat and selected invertebrate prey of shorebirds, wading birds, and other seabirds. The initial review of each of the seven works gives excerpts and major findings from each without comments or interpretation.

I complete the review with an analysis of what the major findings are from each, and how they relate to impacts of rockweed harvest algal habitats/invertebrate prey.

Finally, I present what I believe to be a logical conclusion of the efforts to date in terms of closed areas for rockweed harvesting.

I. Published works

Blinn, B.M., Diamond, A.W., Hamilton, D.J. 2008. Factors affecting selection of brood-rearing habitat by Common Eiders (*Somateria mollissima*) in the Bay of Fundy, New Brunswick, Canada. Waterbirds: The International Journal of Waterbird Biology 31(4), 520-529.

This study quantified the relative importance of factors affecting selection of brood-rearing areas by Common Eiders (*Somateria mollissima*) according to duckling age. The objective was to assess the possible effect of rockweed harvesting on Common Eider broods – that is, what constitutes "good" brood-rearing habitat for eiders. Field work was carried out on Grand Manan Island, and "on the mainland." Food availability was assessed indirectly: 1) rockweed density (clumps per square meter); and, 2) height (cm).

Major findings: 1) Duckling abundance varied significantly with numbers of breeding pairs of Great Black-backed Gulls on colonies within five km of study sites on both the mainland and on Grand Manan Island; 2) There were no significant differences in either rockweed density or plant height between harvested and control sites on both the mainland and on Grand Manan Island; 3) Abundance of ducklings less than 2wks old was initially higher in harvested vs. control sites (a mean of 2 vs. a mean of 0.6 individuals); however, young ducklings were not observed in harvested sites past July, while a few young ducklings were still detected in some unharvested sites in late July; 4) Duckling numbers increased as rockweed density increased; 5) Abundance of younger ducklings on the mainland (not Grand Manan Island) was negatively affected by rockweed density, but this effect was driven by a single site (Welch Cove – unharvested control site) where a peak in duckling numbers was recorded; and 6) Duckling abundance in all age-classes combined was negatively affected by commercial and recreational boat traffic on Grand Manan Island, but not ducklings less than 2 weeks old; no effect of boating was found on all age-classes of ducklings tested on the mainland.

Hamilton, D.J. 2001. Feeding behavior of common eider ducklings in relation to availability of rockweed habitat and duckling age. Waterbirds: The International Journal of Waterbird Biology 24(2), 233-241.

For several years prior to 2001, Common Eider duckling survival in the Bay of Fund was quite low (4-8%) due primarily to intense predation by Great Black-backed Gulls (*Larus marinus*). Ducklings are most vulnerable to predation during the first two weeks of life, and food availability during this time is critical to enable them to grow through this window of vulnerability/susceptibility. This was an observational study to examine the feeding behavior of Common Eider duckling as a function of their age and the availability of rockweed. Birds were divided into three age classes: I – extends until the first feathers appear (ca. 3 wks); II – from the appearance of feathers until all down is replaced (3 – 6 weeks); and, III – to fledgling (ca. 8 weeks). All observations were recorded near Indian Point, St. Andrews, New Brunswick, Canada from 5 June to 19 August 1996.

Major findings: 1) Although rockweed covered only ca. 20% of the study area, 75% of all age classes of ducklings were observed in areas where rockweed was present; 2) Duckling feeding method depended on their age – older ducklings spent more time diving (twice as much when rockweed was available to them) and less time dabbling (tipping up, swimming with head submerged, and picking invertebrates off exposed rockweed); 3) Ducklings dabbled over three times more and dove half as much when rockweed was available as when it was unavailable or scarce; 4) Class I ducklings spent nearly 50% of their time feeding when rockweed was available, compared with just over 30% when it was absent; 5) During periods of high tide, only Class I ducklings dabble while the older ducklings dive exclusively to obtain prey.

The author cites three possible negative effects of rockweed harvest on Common Eider densities due to: 1) potential food shortages; 2) physical disturbance; and 3) changes in the physical structure of the rockweed canopy. The author cited her Ph.D. dissertation that showed that at a 50% reduction of biomass there was no lasting effect on canopy invertebrates in small 7m x 3.5 m patches in the rockweed bed. Ducklings use rockweed habitat from June to August. Water-based disturbances have been shown to disrupt duckling behavior for 20-35 minutes following an encounter; therefore, harvesters should delay working in important duckling feeding areas until early August after which time the ducklings are large enough to dive successfully and are no longer vulnerable to gull predation. Finally, canopy height is reduced when harvested that results in less rockweed floating at the surface during a tidal cycle and invertebrates would be inaccessible for longer periods of time. There is no significant reduction in canopy height when less than 44% of the clumps in a harvested patch are cut, but the canopy is lowered when more than that is disturbed.

Hamilton, D.J., Nudds, T.D. 2003. Effects of predation by common eiders (*Somateria mollissima*) in an intertidal rockweed bed relative to an adjacent mussel bed. Marine Biology 142, 1-12.

Because eider ducklings and females feed predominantly on invertebrates found in association with rockweed, and because ducklings are dependent on this habitat for food during the first weeks of life, this study investigated whether rockweed harvesting affects the food supply for ducks. They used predator exclosures and simulated rockweed harvest to study the effect of predation by Common Eiders, in combination with rockweed harvest, on invertebrate biomass and species composition in Passamaquoddy Bay (Indian Point, St. Andrews), New Brunswick, Canada.

They took 12 experimental plots (7 x 3.5 m) and in six plots, simulated a rockweed harvest by removing 50% of *Ascophyllum nodosum* biomass ("using garden sheers, we cut off half of each plant, or cut to a minimum length of 30 cm, whichever was higher"). In each of the 12 plots, they installed a predator-exclusion cage and a paired control (open to predation). Only the top of the cage (1.5 m x 1.5 m x 30 cm high) was covered with mesh (3 cm). There was no mesh on the sides of the cages so that other predators (crabs, fish, etc.) could enter and exit the caged plots. Cage and control plots were set up in June 1994 (when first sample was taken), and the plots were sampled in August 1994, and every four months until August 1996 (this was a total of 8 sampling dates). Upon each sampling date, all invertebrates were removed, enumerated, and identified to species in four 100-cm^2 blocks within the middle square meter of each caged and control plot.

Major findings: 1) Rockweed harvest had no effect on invertebrate species richness or biomass, or on dry tissue biomass of common species in the system; 2) More whelk (*Nucella lapillus*) and periwinkle (*Littorina littorea*) biomass occurred under exclosures vs. controls, but differences typically were small; 3) In only one month (August 1994, 2 months into the experimental period), was predation influenced by rockweed harvest - more biomass was observed in the exclosures vs. controls in unharvested plots and an opposite trend in the harvested plots; 4) By the end of the trial, whelk biomass did not differ significantly between harvested and unharvested plots.

The authors state: "Rockweed harvest had no detectable effect on the invertebrate community. Harvested and unharvested plots did not differ in total invertebrate biomass, species richness, or in the relative abundance of individual species." Also, "While length (of rockweed plants) in the harvested area was still significantly less than it had been before harvest, volume had returned to pre-harvest levels (1 year later) suggesting that the plants changed shape. These data suggest that as the rockweed recovered, both harvested and unharvested plots had the same amount of algal surface area available for periwinkles and other species."

Phillippi, A., Tran, K., Perna, A. 2014. Does intertidal canopy removal of *Ascophyllum nodosum* alter the community structure beneath? Journal of Experimental Marine Biology and Ecology 461, 53-60.

The work here examined effects of rockweed harvesting on sediment structure beneath the *Ascophyllum nodosum* canopy and on the invertebrate populations associated with the sediments (infauna) and mobile megafauna (green crabs, *Carcinus maenas*; periwinkles, *Littorina littorea*). The study was conducted at two sites. In 2011-2012, the authors established experimental plots along the western shore of Sears Island (cobbles and boulders predominated at this site, with a sandy substrate beneath). No commercial harvesting occurred at this site. In 2013, they used a commercial site in Muscongus Bay (northwest side of Round Pond), where the primary substrate was ledge. The bed they sampled was about 60 m long, with half of it being harvested commercially (mechanical harvester) in July 2013, while the other half remained unharvested.

In May 2011 near Sears Island, the authors created two transects in the mid intertidal and created 27 2m x 2m plots along each transect. The *Ascophyllum* in 12 plots along each transect was cut using hand shears down to a height of 40.6 cm (16 inches). The remaining 15 plots along each transect were left alone as controls. Six harvested and unharvested plots were sampled four times from June to September. Sampling occurred in the internal 1m x 1m area of each plot. Six unharvested plots were sampled in May. They sampled green crabs and periwinkles within a 0.5 m x 0.5 m quadrat and infauna from two sediment cores per plot that were sieved down to a 500-micron (0.5 mm) size.

In 2012, they created a third treatment group at the Sears Island site (harvested to 20.3 cm, or 8-inches "which more closely represents legal cutting lengths in some other countries"). They sampled from 1m x 1m subplots each month from May through October. In addition, they anchored 4 clay bricks in each treatment plot in May. Each month from June-October all amphipods were counted on each brick.

In 2013, they set up an experiment at the Round Pond study site. Five infauna samples were taken from each of the two sides of the *Ascophyllum* bed both 1 week pre-harvest and 2 weeks post-harvest. Mobile megafauna were sampled using three 0.5m x 0.5m quadrats placed randomly within each treatment (cut vs. control).

Major Findings: 1) Green crab densities were significantly depressed in harvested plots at Sears Island in 2011 whereas densities of periwinkles increased between 70-130% in the harvested vs. control plots; 2) Similar trends occurred in 2012 at Sears Island; 3) Other invertebrate species found in sediments (oligochaetes – marine worms from the Phylum Annelida; nematodes – marine roundworms in the Phylum Nematoda; *Streblospio benedictii* – polychaete worm from the Phylum Annelida; *Mya arenaria* – bivalve, the soft-shell clam; *Jaera marina* – isopod – small, mobile crustacean that grazes detritus and living plant matter) varied seasonally, but exhibited no treatment effects on their abundance; 4) Results from 2012 corroborated those from 2011 with two notable exceptions: a) recruits of the bivalve *Mya arenaria* appeared to have increased abundances in the harvested plots during peak recruitment time; and, b) amphipods, primarily *Gammarus* spp. (a small [< 12 mm in length] crustacean grazer and detritivore) “seemed” to be less abundant in the 20.3 cm (8-inch) cut plot; however, high variability in numbers prevented a powerful enough statistical test to detect any significant treatment effects; and, 5) There were no observable differences between the two sides of the *Ascophyllum* bed at Round Pond, either before or after harvesting, for any invertebrate species sampled, including green crabs and periwinkles.

II. Unpublished manuscripts, final reports, and dissertations

Beal, B.F., Ugarte, R.A. Short-term effects of rockweed harvesting on algal biomass and selected rocky intertidal organisms. Unpublished manuscript.

This field experiment was conducted at two rocky intertidal locations in the Jonesport-Beals area of downeast Maine (northwestern side of Head Harbor Island, Jonesport – Eastern Bay; northeastern side of Pig Island, Beals – Moosabec Reach) during 2012-2013 to determine the interactive effects of rockweed harvesting and tidal height on rockweed biomass and abundance of the four most numerically abundant macroinvertebrates (*Littorina obtusata* (the smooth or flat periwinkle), *Littorina littorea* (the common periwinkle), *Carcinus maenas* (the invasive green crab), and *Mytilus edulis*(blue mussel).

On 6-7 June 2012, two adjacent plots (35m x 30m) that covered the rockweed bed from the upper to lower intertidal were established at each site (sites were comprised of ledge, large boulders, and scattered cobble). One plot served as a control while the other as a harvesting (cutting) treatment. Initial algal biomass and invertebrate abundance within each plot was estimated at low tide at each of three tidal heights (upper, mid, low). Quadrat samples were taken along a 30m transect line within each tidal height and plot at both sites. Within each quadrat, all macroalgae was collected by cutting the interior perimeter of the quadrat with scissors and placed, along with any mobile invertebrates and epifauna into a labeled plastic bag. This was followed by scraping the holdfasts off the substrate and removing any large invertebrates. On 8 June 2012, a commercial rockweed harvester using a cutter rake harvested the rockweed in each cutting plot at each site during times when plots were tidally inundated. A total of 3,594 kg and 2,060 kg was removed from the plot at Pig Island and Head Harbor Island, respectively (harvesting intensity – 23.3% and 16.9% biomass removal, respectively). Post-harvest sampling occurred on 10-11 June 2012 (after 2-3 days), 18-19 July 2012 (after 40-41 days), and 28-29 June 2013 (after 386-387 days).

Major findings: 1) *Littorina obtusata* was the most numerically abundant macroinvertebrate in pre- and post-harvest samples at both sites, and mean densities (pooled across tidal heights, sites, and cutting treatments) dropped by ca. 40% after the harvest (from mean of 5.5 to 3.2 individuals per quadrat); 2) After cutting, densities of *L. obtusata* were similar across tidal heights, whereas densities in control plots declined by 46% from upper to lower shore levels; 3) *Littorina littorea* densities at both plots at Pig Island and in the control plot at Head Harbor Island were higher at the mid and lower shore level in both control and harvested plot; however, no significant differences in mean density occurred between tidal heights in the harvested plot at Head Harbor Island; 4) No effect of harvesting was observed for green crabs; and, 5) Blue mussel densities were generally highest in the control plot at Pig Island, and significantly greater than in harvested plots (3.85 vs. 0.43 individuals per quadrat), whereas densities at the Head Harbor Island site were too low to detect any harvesting effects.

Fegley, J.C. 2001. Ecological implications of rockweed, *Ascophyllum nodosum* (L.) le Jolis, harvesting. Ph.D. dissertation. University of Maine. Orono, ME 241 p.

Chapter 2. Short-term effects of *Ascophyllum nodosum* harvesting on the intertidal community.
This effort was a field experiment at four moderately sheltered intertidal locations in Maine that tested the general hypothesis that altering the fucoid canopy height affects the abundance and composition of the associated fauna and floral community. Study sites were Castine, Blue Hill Falls, Lamoine Beach, and Rackliff Island. All sites supported a dense, continuous cover of Ascophyllum (> 70%). At each site, three replicate 5m x 5m plots were established for each of three treatments: 1) *Ascophyllum* uncut (control); 2) *Ascophyllum* cut 36 cm above the holdfast; 3) *Ascophyllum* cut 18 cm above the holdfast. All plants were hand-cut. Every 5-6 weeks from June 1997-June 1998, three 25 cm x 25 cm quadrats were sampled from within each of the larger plots at each study site to estimate faunal abundance. Only species whose mean numerical abundance was >1 were included in the analyses.

Major findings: 1) Thirty-three different invertebrates were found during the experimental period (10 were regularly found and analyzed for treatment differences); 2) Harvesting significantly affected six of the 10 common invertebrates that use *Ascophyllum* habitat (*Carcinus maenas* – the invasive green crab; *Dynamena pumila* – an epiphytic (a species that lives on, and is attached to macroalgae) colonial hydroid (Phylum Cnidaria, Class Hydrozoa); *Halichondria* spp. (an amorphous, suspension-feeding sponge); *Littorina obtusata* (the smooth, or flat, periwinkle that feeds primarily on fucoid algae which includes *Ascophyllum nodosum*); *Nucella lapillus* (the predatory dogwhelk – feeds primarily on barnacles and mussels); and, *Spirorbis spirorbis* (an epiphytic, calcareous, coiled-in-a-tube polychaete worm that measures ca. 5 mm in diameter and lives on the fronds of *Ascophyllum* and *Fucus*); 3) Abundance of green crabs, the colonial hydroid, sponge, periwinkle and polychate worm were higher in control plots compared to plots cut at the 18 cm height; 4) For dogwhelks, there was no difference between controls and the 18 cm treatments.

Chapter 4. Ecology of *Ascophyllum* harvesting: effects on associated invertebrate assemblage
This study examined the consequences of rockweed harvesting on invertebrates associated with the macroalgal community over a two-year period. The experimental design and study sites were identical to that described in Chapter 2. The experiment was initiated in 1997, and harvesting was done using hand shears. Every five to six weeks throughout the two-year study, a 25 cm x 25 cm quadrat was used to sample both mobile and sedentary species within 5m x 5 m plots.

Major findings: 1) Thirty-nine invertebrate taxa were found in the experimental plots over the two years, and 10 were in sufficient quantities to warrant statistical analyses; 2) Green crabs were not affected by rockweed harvesting at three of the four sites. At Rackliff Island where higher baseline densities of rockweed occurred, harvesting negatively affected crab abundance; 3) The two most abundant periwinkles, *Littorina littorea* and *L. obtusata*, were unaffected by canopy removal; 4) Blue mussel abundance was moderate to high at Blue Hill and Lamoine, respectively, and low to zero at Castine and Rackliff Isand, respectively. At Lamoine, highest densities of mussels occurred in the 18 cm-cut plots, followed by controls and then the 36-cm cut plots; 5) Mean abundance of the predatory gastropod, *Nucella lapillus*, and the grazing gastropod, *Tectura testudinalis* (limpet), was not significantly affected by the cutting treaments; 6) Abundance of sessile, understory species such as *Dynamena*, *Halichondria*, recruits of *Mytilus edulis*, and the barnacle, *Semibalanus balanoides*, all varied in complex ways according mostly to differences in sites and sampling dates. For example, when present at high densities (Rackliff Island), percent cover of *Dynamena* in control plots was significantly higher than in either of the cutting treatments. *Halichondria*, the breadcrumb sponge, varied significantly between sites, but no cutting treatment effects were detected. Mytilus recruits occurred only at one site (Lamoine), and in the year when the cutting occurred (1997), recruits occurred in greatest abundance in control plots, but this effect was short-lived as mussel recruits in

1998 were highest in the 18-cm cut plots. Effects of harvesting on acorn barnacles were not significant at Blue Hill and Rackliff Island; however, at Castine in 1997, barnacle percent cover increased significantly in plots associated with the 36-cm treatment, but in 1998 increase in barnacle abundance occurred in the control plots. The pattern at Lamoine was quite different with a peak in barnacle abundance occurring in the 18-cm cut plots.

Dr. Fegley concluded in the Discussion: “The apparent homogeneity of the structuring species, in this case *Ascophyllum*, does not necessarily mean that the associated communities are similar. With *Ascophyllum* communities being so different from site to site, regional or coastwide harvesting impacts will be difficult to assess.”

Trott, T.J., Larsen, P.F. 2012. Evaluation of short-term changes in rockweed (*Ascophyllum nodosum*) and associated epifaunal communities following cutter rake harvesting in Maine. Department of Marine Resources, W. Boothbay Harbor, ME. 33p.

This study was undertaken to examine the effectiveness of current regulations on cutter-rake harvesting for preventing and/or minimizing impact on rockweed and associated macro invertebrates. Short-term recovery, two months following a single harvest, was the time course for evaluating disturbance effects.

The study site was located in Cobscook Bay in Shackford Head State Park, and the field experiment was initiated in July 2008. A modified Before-After-Control-Impact (BACI) design was employed with stratified random destructive sampling used to evaluate potential effects of harvesting. Two adjacent plots (50m x 20m) were established. Within each plot, four quadrats (25 cm x 25 cm) were sampled along a high, mid, and low intertidal transect. To assess fauna and algal biomass prior to harvest, algal biomass within each quadrat was cut just above the holdfast (< 1 cm) and processed in the laboratory where biomass estimates were made along with abundance estimates of mobile epifauna. Other fauna that remained after removing rockweed was collected with forceps.

Immediately after this sampling, rockweed was harvested in the experimental plot by a professional harvester from Acadian Seaplants Ltd., New Brunswick, using a cutter rake. Approximately 17% of the biomass (1.25 wet tons) was removed from the experimental plot in 1.5 hr. Both control and experimental plot were subsequently sampled using the same technique as described above in September 2008.

Major findings: 1) Rockweed biomass in the experimental plot was greater following harvesting while the control plot showed no significant change; 2) A total of 105 putative species were identified, extrapolated densities ranged from 1,168 to 34,656 individuals/m^2, and there was no significant impact of harvesting on the number of individual animals on rockweed thalli, or substrate; 3) There was no significant impact of harvesting on the number of species found on rockweed thalli or substrate; 4) There was no significant impact of harvesting on the abundances of the three periwinkle species, *Littorina littorea*, *L. obtusata*, or *L. saxatilis* on either rockweed thalli or substrate.

Analysis of Major Findings

Blinn et al. (2008) examined eight rockweed-harvested sites and four control sites. Each site occurred along 1 km of coastline and extended approximately 500 m offshore. The study was conducted in 2000 and 2001, and resulted in over 1,400 hours of observations. The authors examined the relationship between Great Black-backed Gull nests within 5 km of a study site and total number of ducklings and found that trends varied between mainland and Grand Manan Island. On the both the mainland and Grand Manan Island, there was no correlation between number of nests and total number of ducklings for control sites; conversely, for harvested sites, the relationship was quadratic (parabolic) on the mainland with highest number of ducklings occurring at a nest density of ca. 175 and lowest numbers occurring at both 0 and 380 nests within 5 km of the study site, and on Grand Manan Island, there was no correlation between the two variables. ***Clearly, any effects on Great Black-backed Gulls on eider ducklings due to rockweed harvesting are minimal or non-existent.***

In terms of habitat degradation, no significant differences were observed in either rockweed density or plant height between harvested and control sites. Boat traffic (both commercial and recreational) had a negative effect on duckling abundance across all age classes on Grand Manan Island, but not on the mainland. The authors examined the effect of intertidal slope on duckling numbers and found that harvested sites with steep slopes supported the fewest ducklings; however, duckling numbers were similar in all other sites regardless whether sites were harvested or control.

The authors conclude in their Discussion: "***Finally, results provide limited evidence of an adverse effect of rockweed harvesting on ducklings***."

Hamilton (2001) did not conduct an experiment to assess effects of rockweed harvest on Common Eiders, but did comment on the possible effects. 1) Common Eider ducklings have little effect on the numbers of their invertebrate prey (Hamilton – Ph.D. dissertation – 1997), so ducklings are probably not food limited; 2) She simulated a harvest by removing 50% of the rockweed biomass from small (7 m x 3.5 m) patches in the rockweed bed. "Even this level of removal had no lasting effect on canopy invertebrates." 3) Physical disturbance during rockweed harvest may both limit feeding opportunities for ducklings and increase their risk of predation. (Hamilton cites a study by Åhlund and Götmark [1989] from the Swedish west coast where 5-10 small boats used for household fishing, several trawlers, and extensive recreational boating occurs from late May to September. That study showed that disturbance by boats can markedly raise gull predation on eider ducklings.) 4) Rockweed removal can reduce overall canopy height that could float at the surface for less time during each tidal cycle making invertebrates less accessible; however, "there is no significant reduction in canopy height when less than 44% of clumps in a harvested patch are cut."

Since harvested patches are restricted to a 17% removal in Maine, the current level of harvesting would seem to be appropriate in terms of having no biologically significant effect on common eider ducklings.

Hamilton and Nudds (2003) used predator exclosures and simulated rockweed harvest to study the effect of predation by common eiders, in combination with rockweed harvest, on invertebrate biomass and species composition in Passamaquoddy Bay, New Brunswick. They showed that rockweed harvest (a removal of 15.4% - 25.1% of the biomass in 1995 and 1996, respectively) had no effect on invertebrate species richness, biomass, or on the relative abundance (dry tissue biomass) of common species in the system (limpets, mussels, common periwinkles, smooth periwinkles, and dogwhelks). This led the authors to state: "Rockweed harvest had no detectable effect on the invertebrate community." Harvested rockweed volume after one year returned to pre-harvest levels and algal surfaces were similar in both harvested and unharvested plots.

This work indicates that the level of rockweed harvesting simulated by their treatments was not sufficient to have a negative impact on invertebrates compared to their controls.

Phillippi et al. (2014) conducted three field trials to assess the impacts of rockweed harvesting (i.e., canopy removal) on benthic invertebrates. They conducted two field experiments at Sears Island where they removed the canopy to 16-inches above the benthos in 2m x 2m plots and conducted pre- and post-harvest sampling of benthic invertebrates at a commercially harvested site in Round Pond (Bristol, ME). Green crab numbers decreased and periwinkle numbers increased in abundance when *Ascophyllum* was cut.

Although Phillippi et al. concluded that the "overall lack of effect of canopy removal on the invertebrate community is surprising," the nature of the intertidal environment is such that organisms are well-adapted to withstanding these sorts of disturbances.

Conclusions

Taken together, these published and unpublished works are, at present, our best scientific efforts from Maine and New Brunswick to understand how rockweed removal and/or harvesting affects intertidal habitat and invertebrate prey densities. The major theme of these collective efforts is that any negative effects on habitat and invertebrate densities due to removal/harvesting of rockweed are short-lived or were not statistically detectable.

Therefore, I reject the rationale for large closures of the Maine coast that the Rockweed Working Group has discussed to date using information such as: "Negative impact from rockweed harvest is undocumented." This phrase is without merit as the statement ignores these scientific studies. Therefore, there is no reason to adopt the precautionary principle.

Can or should more research be conducted on the effects of rockweed harvesting as a potential disturbance agent on waterfowl populations? Absolutely; however, rockweed harvesting is only one of a number of potential disturbance agents that could affect waterfowl population numbers. At various times of the year and in various habitats, other potential disturbances include: lobstering, clamming, worming, scalloping, periwinkling, sea urchin and mussel harvesting, and efforts should focus on the relative effects of each of these potential disturbance agents to waterfowl populations.

This research should occur in areas (at least ¼- to ½-mile stretches of the coast) that are closed to rockweed and other commercial harvesting – a marine protected zone. I suggest a minimum of three such zones spread out along the Maine coast be committed for this work. In addition, the zones could be used by other scientists to study effects of disturbance related to commercial fisheries on other marine populations and communities. Funds for these studies could be generated through a number of avenues that are under the auspices of the Maine Department of Marine Resources, including, but not limited to: 1) The Seaweed Management Fund; 2) The Scallop Research Fund; 3) The Sea Urchin Research Fund; 4) The Lobster Fund; 5) The Shellfish Fund; and, 6) The Marine Worm Fund. In addition, funding can be sought from other organizations such as the Maine Technology Institute, Maine Aquaculture Innovation Center, Maine Sea Grant College Program, and the Maine Coastal Program.

Results from studies conducted in and around these protected zones will help to enhance our understanding of how commercial marine harvesting impacts populations of important waterfowl.