TASK FORCE REPORT

on

Algal Fouling

in

Broad Sound and Nahant Bay

for

Commissioner M. Ilyas Bhatti

Metropolitan District Commission

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REPORT OF THE ALGAL TASK FORCE CONCERNING FOULING OF SHORELINES OF NAHANT BAY AND BROAD SOUND, MASSACHUSETTS

INTRODUCTION

The beaches of Nahant Bay have long experienced (Lynn, Lynn Item(1902) a generally continuous and often massive perturbations resulting from populations of an unusual free living planktonic form of Pilayella littoralis, commonly, the most abundant attached brown alga in the North Atlantic. Formerly limited to Nahant Bay and its beaches, large populations of this free-living seaweed now perennate (exists year to year) in Broad Sound and also inundate its beaches. Broad Sound, located southeasterly of Nahant Bay and separated from it by causeways which connect the islands of Little Nahant and Nahant to the Mainland at Lynn. While P. littoralis is clearly detrimental to the aesthetic qualities of these coastal areas it is not in any manner directly harmful to man, to other marine plants or to marine animals in Nahant Bay and Broad Sound areas. Because of the serious nuisance qualities presented by the alga, especially in the beach areas controlled by the Metropolitan District Commission (i.e., Revere, Lynn and Nahant), Commissioner M. Ilyas Bhatti appointed a Task Force composed of members familiar with P. littoralis, the history of the free-living Pillayella perturbation and diverse aspects logistics, regulations and the Bay area in relation to this large and pervasive problem.

OBJECTIVES

The objectives of the Task Force were to assemble and assess existing knowledge concerning the Nahant Bay and Broad Sound Pilayella populations, evaluate methodologies currently used to remove the alga from perturbed beaches, to attempt to

aid in beach management and to suggest recommendations of additional investigations concerning the removal and the possible elimination of free-living Pilayella from these areas. To these ends the Task Force focused on a general review of the problems associated with planktonic (free-living) Pilayella, its removal from the beach areas, possible means of disposal and utilization options. Task Force meetings were held as an open forum to discuss the above agenda.

The following sections of this report contain a synopsis of the Task Force discussions and reflect consensus of its members on these issues. It is the committee's overall position that the abundant growth of Pilayella littoralis in Nahant Bay and Broad Sound is probably a response to eutrophication of the near-shore areas of these embayments.

PROBLEM AND RELEVANT GENERAL DETAILS

The perennial occurrence of Pilayella littoralis in Nahant Bay and, more recently, in Broad Sound, in massive amounts in both areas, constitute a serious problem of beach management. Much shoreline in these embayments is continuously perturbed by large quantities of cast Pilayella, sufficient in amount to deter bathing, recreational beach use and create highly offensive odors.

Previous investigations of Nahant Bay fouling identified the responsible organism, determined its optimal and minimal growth requirements and characterized the major nutrient regime

in Nahant Bay. Significantly, these studies determined the life history of free-living Pilayella and discovered three previously unknown methods by which the alga increased its populations. During these investigations, supported in large part by MDC funding, Pilayella perturbation only occurred on Nahant Bay beaches. Routine surveys of peripheral beach areas to the north and south of Nahant Bay during the 1970's and early 1980's showed only small amounts of the alga in inner Broad Sound. Since 1987 large casts of the alga are of common occurrence in inner Broad Sound where its populations now perennate and inundate all of the beaches in this area. The southward movement of the Pilayella population from Nahant Bay to Broad Sound is attributable to prevailing wind and currents to the southeast from Nahant Bay. Its occurrence as a perennating population of the free-living alga in Broad Sound is attributable to the physical character of the embayment and a nutrient-rich environment. It is biologically significant that the unique ball form of free-living (unattached) Pilayella, as a perennial population occurs only in Nahant Bay and Broad Sound. In less than one decade these perennial populations of the alga have approximately doubled the extent of coastal areas in which they occur.

Free-living Pilayella littoralis is unquestionably a mutant of the widespread attached form of this species. Attached Pilayella occurs as a cosmopolitan species in temperate to cold water marine areas. Why is Nahant Bay the initial site of the free-living species? The answer to this question may never be known. Certainly, the alga has been in

Nahant Bay since the late 1800's and probably much earlier. Why the free-living alga is so abundantly productive is also ambiguous but the embayment habitat and a surfeit of major nutrients appear requisite. The export of Pilayella from Nahant Bay and Broad Sound by southerly directed currents is a certainty; for example, the free-living, ball form of the species has been collected along the outer shore of Cape Cod but it does not perennate as a population in these open coastal areas. The question is not whether but when will the alga perennate in another embayment to the south of Broad Sound.

Luxuriant populations of free-living Pilayella littoralis, their subsequent depositions, or casts, which accumulate on the shorelines and cover the intertidal, constitute the basic socio-biological problem. The problem is manifest in generally poor aesthetic conditions which prevail in the perturbed areas specifically, generation of unpleasant odors that permeate shorelines areas, repulsion by humans to tactile contact with a gelatinous brown crud/slop centimeters in depth on the shore and porridge-like masses in the sea, and the visual unsightliness of dark brown algal covered beaches.

Foul odors in Nahant Bay and Broad Sound beach areas are commonly offensive especially during warm periods. Odors result from anaerobic decomposition of sand covered Pilayella littoralis and have a disagreeable hydrogen sulfide (rotten egg),

character. Sulfur compounds (sulfides) are abundant in both algal cell walls and in seawater and are liberated in gas form as the organic material decomposes.

Algal burial in sand and resulting decomposition depends in large part on beach topography. Accumulation and burial is especially evident along Lynn Beach owing to the lack of an extensive forebeach and characteristic wave energies related to wave reflection by a sea wall. Algal burial at Revere Beach tends to be less severe owing to an extensive forebeach of low relief and more uniform dissipation of wave energy.

Physical contact by humans with the brown alga, whether on shore or in the water, is disagreeable, especially to unknowing public. Whether thickly gelatinous on shore or free-living floating small brown balls, some algal material is retained on one's body with contact. Direct experience with the alga is physically and psychologically unpleasant. The appearance of the floating masses and the prevailing noxious odors both suggest physical repulsion.

Algal perturbed beaches have few positive aesthetic qualities. Even during minimal periods of beach cover by Pilayella the shore is mottled and unattractive, especially when contrasted to the white and yellow sands of other beaches in the immediate area of coastal Massachusetts.

HEALTH RISKS FROM CONTACT WITH PILAYELLA

There are no health risks attributable to contact in any form with Pilayella littoralis. Reports that some individuals have experienced varying degrees of nausea after contact with sulfurous odors in beach areas may be credible but have yet to be substantiated.

GROWTH DYNAMICS AND POPULATION CHARACTERISTICS

Productivity of Pilayella littoralis within Nahant Bay and Broad Sound is unusually high in comparison to known growth rates of other filamentous and thalloid marine algae. Algal productivity (total amount of Pilayella formed) within these embayments is substantial relative to the amount of cast Pilayella at a given period. The amount of Pilayella deposited onshore might be compared to "grass clippings from an offshore lawn." The offshore free-living algal population continuously moves shoreward as "on a one way conveyor belt" driven by wind, waves and currents. An unknown quantity of the free-living population is also exported from Nahant Bay and Broad Sound by essentially southeasterly currents to pass into southern greater Massachusetts Bay. Undoubtedly some of this Pilayella represented the 'inoculum' to initiate the current Broad Sound Pilayella population.

Growth dynamics of Pilayella littoralis in situ and in laboratory cultures, have been reported to the MDC by Wilce, et. al. 1987 and in Pregnall and Miller, 1989. Pilayella biomass doubling times range from 6-10 (26) days depending on temperature, nutrients and light variables. Each of these growth factors is optimal for Pilayella growth in Nahant Bay and Broad Sound during the entire year. The alga has an especially strong affinity for nitrogen (compounds) uptake which, with its planktonic life form and filamentous habit, permits enhanced absorption properties. The free-living form of Pilayella appears to have developed several highly selective means of adaptation to a specific environment, i.e., embayments.

MEANS OF POPULATION INCREASE

Free-living Pilayella has also evolved several selective and extremely efficient methods to maintain and to increase its populations. Each method relies on a specific vector to enhance vegetative propagation, i.e., repetitive simple division of any of the filamentous axes that comprise the Pilayella ball. Each fragment, however small, ultimately becomes another Pilayella ball. Reproduction by spores (asexual means) or gametes (sexual methods) is unknown for the free-living form of the species. Both methods occur commonly in the attached form of Pilayella littoralis but vegetative propagation is of little importance to the attached form.

Increased light and sea water surface temperatures during late summer and early autumn appear to increase photosynthesis and concomitant oxygen liberation. Trapped gasses in the filamentous balls are responsible for large amounts of the Pilayella population to aggregate at the surface. Surface water temperatures are lethal to the filamentous portions of each ball while the multiseriate portion remains viable. Fragmentation occurs and each of the sausage-like segments forms another ball to begin its development in early autumn.

A marine chytrid-like unicellular fungus with late autumn through spring seasonality is responsible for additional Pilayella population increase. Concomitant with the regeneration of new filamentous axes from the old sausage-like fragments, a marine saprophytic fungus saprophytizes young cells of the regenerating Pilayella ball. Necrosis follows with only the weak cell wall material remaining to retain filament integrity. Fragmentation results as a result of mechanical pressures and each fragment, as previously, has potential to form another Pilayella ball. Significant population increase occurs as a result of this fungal infestation as 90-100+ infections may occur in each Pilayella ball. Population increase by the fungal vector continues from autumn through late spring. This phenomenon is novel. Unlike other fungal-host relationships, the fungus actually enhances the host population at the expense of relatively few cells.

A third vector, Gammarus tigrinus, abundant during the warmer months in Nahant Bay and Broad Sound is also responsible for increases in the free-living Pilayella population. It was discovered in the laboratory and in the sea that G. tigrinus uses Pilayella as a food source. 'Bite-size' (2-8 cells in length) pieces of the filaments may pass through the amphipod gut as viable segments and are returned to the sea encased in fecal pellets. Each fragment subsequently germinates into a new filament with the result that the fecal pellet may take on the appearance of a small pin cushion with numerous emergent pins.

Pilayella has three most efficient methods to increase the size of its populations, each a result of vegetative propagation. In large part, these methods occur seasonally and ensures 'bloom-size' populations throughout the year.

CLEAN-UP/REMOVAL METHODS

Prevention of Pilayella accumulation on beaches of Nahant Bay and Broad Sound is mandatory to reduce its decomposition. The degree of efficiency of accumulation prevention depends entirely on the use of an effective collection mechanism and methodologies involved with its use. A proposed clean-up and removal program of all the presently Pilayella pertrubed beaches will require financial support from State and Municipal agencies. Considering the severity and magnitude

of this perturbation it is conceivable that Federal Government agencies should be involved in a positive regional solution.

The present method of algal removal from perturbed beaches is at best a short-lived expedient and only grooms these beaches between tidal periods to enhance their use by the public. Tractors with a 'York Rake' adaption (Belt rubber is fastened longitudinally to the inside curve of each rake to function as a massive squeegee.) remove most of the algal cast from a flat sand beach. This process is expensive, time-consuming and temporarily effective in making the beach presentable to visitors. It involves scraping the accumulations of the saturated algal/sand complex into windrows which are subsequently stockpiled or returned to the sea using a front end loader.

The present method of algal removal has been used extensively at Lynn Beach where the beach is broad with low relief and consistently retains a very wet cast. Beaches with greater relief, e.g., Revere Beach and the Point of Pines, the algal cast drains and dries more readily and can be scraped using a front end loader.

Scraped beach material, using current methods, consists of algae (predominantly Pilayella littoralis), sand and debris. The algal portion of this material consists of less than 2% by weight; the amount of debris is miniscule. The present method of algal removal is in fact principally a

sand displacement technique and secondarily an algal removal method. Both sand and the cast algae are collected, concentrated in local beach areas and subsequently moved to and deposited on the low shore. The short term fate of deposited sand is some seaward displacement of beach sands.

Based on observations and some experimental studies the current method of beach scraping can enhance the development and maintenance of the free-living Pilayella population. There is no information as to the amount of cell nutrients returned to the sea when short-term Pilayella-sand are deposited to the low shore. Some nutrients undoubtedly leach from necrotic Pilayella cells and are absorbed by viable cells. It is readily apparent that the amount of nutrients released to the sea from scraped Pilayella is insignificant compared to nutrient levels in ambient greater Massachusetts Bay waters. Lacking efficient means of collection and disposal of free-living Pilayella, and considering the immediate pressures to attempt beach cleaning, the current procedures of beach scraping, and/or temporary storage of beach material and subsequent return to the sea are justified.

It is clear that the current primitive methods of beach grooming are inefficient and do not contribute to a long-term management of Nahant Bay and Broad Sound beaches. It is also clear that these methods are ineffective in reducing the off-shore ("seed stock") of Pilayella.

Removal efforts should be directed toward removal of stranded, cast algae and more importantly, to intercept and collect drifting Pilayella populations in shallow water before they reach the beach. Equipment necessary to achieve these ends must be developed by engineers in concert with others knowledgeable of the alga and collecting techniques. Optimal collection of Pilayella includes minimal retention of beach sand and seawater, i.e., an essentially uniform mass of the alga partially drained of water.

PILAYELLA DISPOSAL AND OPTIONS FOR ITS RE-USE

The problems of Pilayella disposal have been significant from the outset of beach management by M.D.C. Current grooming practices clearly identifies the question as to what to do with the scraped beach material. The by-product of grooming is essentially beach sand and a relatively small percentage of the mass is represented by Pilayella. In excess of 1000 cubic yards of sand can be routinely collected with present grooming techniques in a three day period. Estimates of costs associated with hauling, disposal at an offsite landfill and yearly replacement of beach sand are unreasonable. The ecological and regulatory impracticality of this disposal procedure and its attendant costs dictates rejection of these procedures as a solution to the problem. If all environmental, cost and regulatory concerns can be overcome then the re-use of the material at other marine locations may be an option.

A relatively small quantity of the sand-algal mixture might be considered as a supplement to dune repair programs

in the immediate area. A small amount of nutrients are contained in the Pilayella mass, useful in the development of beach grass communities. Some efforts to use the sand-algal mixture as dune suppliments and additives to beach grass populations have been accomplished in areas of Nahant Bay. Use of the sand-algal mixture as a dune supplement for its nutrient value is recognized as worthwhile. However, only an extremely small amount of groomed beach material can be used in this manner without transport and removal of the material from the perturbed beach areas to other suitable loctions.

Stockpiling of groomed beach material is identified as another option of temporary disposal. When the magnitude of the perturbation during summer is considered, and the amount of requisite grooming during this period, the number and size of piles of sand and algae in beach areas may be prohibitive. Stockpiling of sand-algal mixture has several limitations. Results of stockpiling may be aesthetically repulsive and encourage public protest to the appearance and possible odors generated. Suitable beach stockpile areas are limited without the use of transport vehicles. Stockpiling the sand-algal mixture is partially effective when small amounts of material are groomed over long time periods. Stockpiling is not efficient in attempts to reduce the Pilayella population. In fact, as suggested earlier, stockpiling can enhance the population by the release of nutrients to the sea from decomposing Pilayella. The data concerning pools

and amounts of available nutrients to rapidly growing Pilayella in contrast to the weak estimates of nutrient amounts from stockpiled materials does not suggest the elimination of the stockpile technique.

A third option of disposal of groomed beach material is to return it to the ocean immediately after scraping. The beaches would be groomed only for a period of one tidal cycle, and can be covered by the subsequent tidal period. The relative costs of this procedure for a more satisfied public is a positive consideration. This option does not deter or reduce the Pilayella standing crop and can increase it.

Two additional points remain with respect to Pilayella disposal, reduction and/or elimination as a nuisance population. It is committee consensus to oppose non-marine off-beach landfill disposal of scraped materials. This method while expedient is both environmentally detrimental, unwise, and economically totally unwarranted. As previously mentioned, the re-use of the material in a marine environment may have promise provided it is environmentally sound and cost effective. The usual replacement source of sand for marine applications is terrestrial due to cost considerations. Lastly, a cautionary comment, supported by the committee, concerning the absolute rejection of usage of any form of algacide, herbicide, weed killers and the like by those who believe the perturbation in ultimo extremus. Plant specific algacides are unknown with respect to attached marine algae, including the free-living form of Pilayella littoralis. Algacides, herbicides have never proven effective in marine environments especially in coastal areas characterized by both high energy waves and appreciable tidal exchange.

FUTURE NEEDS SECTION

Objectives of future investigations are identified as those that specifically relate to short term management problems and those that address long term solutions, i.e., the ultimate reduction and/or the elimination of free-living Pilayella from Nahant Bay and Broad Sound. Neither avenue of research activity can be addressed unless there is a willingness of Local, State and Federal Governments to give the Pilayella issue priority and to fund and implement studies with wholehearted commitment. Those individuals in the political realm must view this phenomenon as a regional problem beyond the limits of political wards and districts. Consideration of these objectives at this time is especially urgent in view of the expected southward migration of Pilayella into greater Boston Harbor. Occurrence of bloom populations of free-living Pilayella in greater Boston Harbor could result in an ecological perturbation of massive proportions.

Short Term Research Strategies

Short term interim needs are mainly those involved with the development of modified and improved equipment and techniques to remove, dispose or re-use collections of beach algal cast. Equipment must be developed to increase the efficiency of beach scraping. The ratio of algae to sand collected must be increased and the impact of sand lost from the beach environment reduced. Masses of essentially sand-free Pilayella may eventually have a beneficial role in the northeast maritime community but collection techniques are not sufficiently effective and, at this time, use of Pilayella is limited. Equipment needs are everywhere manifest. Currently, only on-shore scraping and collections are made, the results, only cosmetic. Future efforts must include more efficient on-shore scraping and efficient collection methods in shallow off-beach environments. Collections in inshore shallow water may show more promise to concentrate free-living algae, essentially free of sediments, and its collection by adaptations of existing inshore oceanographic vacuum/suction devices.

Several other short term research objectives are suggested, all of which relate to public education concerning the free-living Pilayella population or to a study of the general perturbation problem.

a) Development of a written management plan to establish methodologies to handle collected algae is currently appropriate and of much need in the future. Such a handbook would include new technologies to deal with collected algal material and reflect monetary resources allocated to a Pilayella program.

b) Future investigations are needed to explore and consider additional disposal options. These options will be necessary with the development of more efficient algal collection techniques.

c) A study of free-living Pilayella is necessary to determine its viability limits in stockpiled areas. Questions remain as to the regeneration properties of scraped material after it has remained on the beach for various time intervals.

d) Of general interest to the public and funding agencies is the identity of the gaseous by-products of anaerobic decomposition. Health questions from the public are commonplace as to the exact chemical compounds of the gaseous stench.

e) Future responsibilities of a Pilayella Task Force committee should include efforts to become aware of other studies concerned with biological, chemical and physical oceanographical problems associated with Greater Massachusetts Bay. Duplication of research efforts related to Pilayella should be minimized.

Long-Term Research Strategies

a) As previously cited, the need of a "super" off-shore algal collecting device is requisite to ultimately reduce the free-living Pilayella population in Nahant Bay and Broad Sound. This proposal is based on the use of a vessel to harvest (collect) free-living Pilayella.

from water between 3-35 feet depth. This vessel and its appurtenant suction/collection apparatus must be designed to function primarily in regions of the coast immediately seaward of wave surge, the region of immense algal concentrations. Likely sponsors of the development and purchase of this equipment would be the private/commercial community in concert with State and Federal agencies depending on the value of collected biomass and the perceived extent of the perturbation impact.

b) Free-living Pilayella standing crop, its seasonal biomass needs to be assessed. Questions have long remained unanswered as to how much Pilayella biomass exists in a given area at a specific time and how does the populations change biomass amounts over time?

c) A nutrient mass balance and hydro-dynamic model is needed to determine which nutrient sources play major roles in the growth and maintenance of free-living Pilayella. Such information will be useful in the determination of cost/benefits of nutrient sources identified that require reduction. A continuous water sampling program to identify nutrient levels in near and off-shore waters should be considered as a portion of this research.

d) Appointment of a coastal surveillance person(s) to verify the identity of free-living Pilayella from Massachusetts coastal locations other than Nahant Bay and Broad Sound. Possible movement of the free-living Pilayella population should be recognized prior to its perennial establishment in number in other coastal embayments.

e) Economic considerations of free-living Pilayella biomass and its associated perturbations deserve close scrutiny. Currently unanswerable questions are raised as to the economic damage, losses that occur in perturbed areas. Such losses may be associated with devalued properties, recreational dollars lost to local communities, beach clean-up and algal disposal costs. At present there is no cost/benefit analysis concerning beach maintenance.

Analysis of Pilayella organic compounds and their potential marketability should be performed especially of the anticipated collection of immense quantities of this alga, essentially sand-free. Economic profitability of algal products utilization should be examined.

f) Prior to funding future research and development, estimates of costs related to each proposal concerned with Pilayella research should be provided. A suggested scope of services must be developed with identified costs, objectives and schedules of completion. It would be the dual responsibility of a Study Overview Committee (see below) and funding organizations to insure compliance of the research personnel with stated research terms.

GENERAL RECOMMENDATIONS

Establishment of Study Overview Committee is of primary importance. This committee would consist of three to five members familiar with content and scope of previous Pilayella investigations and with expertise related to Pilayella perturbations. At least one member of this committee should be chosen from citizens or public interest groups.

A central funding source should be established by the Commonwealth of Massachusetts that receives and distributes research enabling this committee to function. Committee responsibilities would include direct control of future studies, their relationship to identified Pilayella study objectives, allocation of research monies and maintenance of research schedules.

It is not within the institutional policy of the Metropolitan District Commission to be the sole agent responsible for funding or controlling purse strings for directed research activities. Budgetary constraints and Administrative financial procedures have proved too inflexible and cumbersome for meeting the continuous funding of research programs. The Federal Sea Grant Program, and Massachusetts Bays Program are avenues to be explored as a study center and disbursement mechanism.

SUMMARY

The algal material that accumulates on the shorelines of Nahant Bay and Broad Sound is a brown seaweed (Pilayella littoralis) which in no manner poses health threats to humans. Problems associated with the accumulation of this alga on beaches arise from the generation of nuisance conditions and from gasses generated from the anaerobic decomposition of buried algal masses. Perturbed beach areas must have algae removed from beaches during high depositional and peak recreational periods. Present removal methodologies are inadequate to remove this material from local beaches, such efforts only briefly effect beach cosmetics. Current removal does not reduce the overall algal population and minimally changes beach appearance for only several hours after scraping. More effective equipment must be obtained to improve beach clean-up and reduce the amount of sand (99% by weight) collected in beach scraping. Engineering solutions to these problems are possible, must be developed and be compatible with available monetary resources.

Re-use and disposal of the collected sand/algal mix should be recycled whenever possible for beach grass planting and dune reconstruction/repair. These options have limited value in reality and current practices are the only feasible, albeit unsuitable, alternative.

Local, State and Federal awareness of the potential magnitude and impact of a geographically expanded Pilayella perturbation in coastal Massachusetts is essential. Recognition of the existing problems associated with free-living Pilayella demands implementation to enable our society to alleviate some of the unpalatable conditions associated with Pilayella perturbation. In view of the distributional record of this species into Greater Boston Harbor, decisions concerning future Pilayella control measures and Pilayella perturbation studies must be made and given priority for implementation now.

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