s319 Report 042508
Hand pulling efforts

Under the s319 report, hand pulling of milfoil was one of the tasks. Dudley Pond was treated with fluridone (trade name Sonar) in 2003. Underwater surveys done at the end of the summer and in the early fall indicated that small milfoil plants were coming from the almost dead root crowns. Approximately every 75 feet or so in the areas that had heavy milfoil growth before the fluridone treatment of 8 ppb, one could find a sprig of bright green new milfoil about an inch long coming from the blackened shoots. The blackened shoots were what was left of the milfoil stalks on top of the root crowns after the fluridone had done its work. These blackened shoots were approximately 6 inches high. There was no decision to do anything about the new shoots until 2004. Perhaps that was a first mistake.

By 2004, hand pulling began in mid July and continued into early October. A total of 12,070 milfoil plants were pulled using 153 diver hours. This cost $5,960. The concentration of diver effort was on removing the milfoil from areas that were most likely to get out of control if left alone. By the end of the season, the amount of money allocated had been exhausted, but there was much milfoil remaining in the pond. It was estimated that 40% of the total milfoil that had grown during the year had been pulled, leaving 60% behind. The amount pulled kept the milfoil off the surface of the pond, and put a large dent in the hotspot areas, so that they generally looked like the rest of the pond. This means there were areas that appeared to have scattered milfoil plants, and some areas of the pond that looked like there was no milfoil growing. However, this means perhaps 20,000 milfoil plants were left to overwinter because of a lack of funds, a lack of diver time, and an underestimate of how many plants might grow the year after a low-dose chemical treatment with fluridone (it should be noted that previous treatments with fluridone in such years as 1995 and 1999 were at approximately 15 ppb, but not necessarily kept at that concentration for a long time). It was stated at the end of 2004 that the pond was under “reasonable control.” How wrong that turned out to be.

In 2005, hand pulling began in early July and continued into November. A total of 49740 milfoil plants were pulled using 428.5 diver hours. The $4,000 of the s319 grant was exhausted by August 8, 2005, with the first 100 diver hours. 12,958 PLANTS WERE REMOVED WITH S319 MONIES. Divers observed a healthy population of a najas species, another invasive plant, but one that does not generally reach the surface. The najas carpeted much of the bottom, growing to five or six feet in thickness by the end of the summer. It generally helped to prevent the re-rooting of the milfoil floating fragments. However, divers noted some milfoil growth coming through the najas carpet. This growth likely came from sub-sediment stolens. Since this is the main method of milfoil self propagation, it is hypothesized that the mother plant can support the growth of the daughter plants until they can emerge enough from the najas carpet to photosynthesize on their own, thus producing their own food.

Recognizing the high level of infestation in 2005, the Wayland Surface Water Quality Committee allocated an additional $12,000. After that the Dudley Pond Association

allocated additional monies totaling $1,140. A total of $17,140 was spent on hand pulling in 2005. Divers continued until it was too cold to dive in November. It was estimated that 30% of the total population of milfoil had been hand pulled, even though almost four times as many plants had been pulled this year compared to 2004. This means that over 100,000 milfoil plants were left in the pond to overwinter a second winter in some cases. The 12,958 plants pulled with s319 money were approximately one quarter of what was removed during the entire year. Given estimates were that only 30% of the total number of milfoil plants were pulled in the entire 2005 diving season, the s319 money represented hand pulling less than 10% of the total milfoil plants in the pond. Considering this was only the second year after a treatment with fluridone, and after a concerted effort in 2004 to remove as many milfoil plants as possible with the funds allocated in that year, the rate of milfoil growth is nothing short of astounding. The concept of “reasonable control” was waning.

In 2006, hand pulling began as early as March, although efforts in earnest did not begin until June. With the realization that the milfoil was growing out of reasonable control by this season, more divers were brought in and more money spent than in any previous year. A total of 140,000 milfoil plants were pulled using 471.5 diver hours. This cost $18,860. The milfoil was at the surface in major portions of the pond. Divers concentrated on pulling areas that had the most use by the public, such as Mansion Beach, Rocky Point, and Priscilla Path. Divers also concentrated on keeping a boating channel open around Dudley Point. This allowed boaters to move from the deeper section of the pond which had little to no milfoil on the surface, to other areas of public access. Weevils were put into the pond this year, and divers avoided those areas. By the time the monies allocated were exhausted, it was certain the battle was lost. The milfoil was so dense that in some of the areas that were hand pulled first in the summer, the milfoil had already grown back almost to the surface in some instances, appearing as if nothing had been done in that area. It was estimated that only 20% of the milfoil population had been pulled that year. Even though this was about 3 times the total number of milfoil plants pulled in 2005, it means over 600,000 plants were likely left in the pond.

One of the reasons diver efficiency increased so much in 2006 was that the milfoil plants were so densely packed that divers said it was like working against a wall of milfoil. Compared to 2004, when divers had to swim considerable distances in some instances to find plants, in 2006, a diver simply went off the side of the boat and began picking. No searching was necessary. The method of hand pulling remained the same in each year, in that a net bag used by lobster divers was carried by each diver. An average of 150 plants could be put into a bag, which weighed approximately 70 pounds wet weight when hauled from the water. Once a diver filled a bag, it was clipped to a line on the side of the boat and another bag taken to be filled. Depending on size of plants and density, a net bag could hold as few as 60 plants to as many as 250 plants. Very few fragments were left behind, especially in the early years. By 2006, just the fin kicks of divers created fragments, which were picked up with surface nets for the most part. Given the amount of milfoil in the pond already, the amount of auto-fragmentation by the plants far exceeded anything the divers left behind.

The following table summarizes data from 2003 to 2007:

Year	Hand pulling $	Number mifoil pulled	Paid diver hand pulling hours	Estimated % of total milfoil removed	Extrapolated remaining number milfoil at end of year	Plants pulled per diver hour
2003	0	0	0	0	Unknown	n.a.
2004	5960	12,070	153.0	40	20,000	80
2005	17,140	49,740	428.5	30	100,000	116
2006	18,860	140,000	471.5	20	600,000	297
2007	0	0	0	0	Millions	n.a.

By 2007, there was the realization that hand pulling would not have any substantive effect, and it was decided to try a harvester and circulators. 32 tons of milfoil were harvested, far outstripping any biomass removal by divers. After about six weeks, the milfoil was back on the surface again. Millions of plants were left in the pond to grow in 2008. One benefit accrued by removing 32 tons of milfoil biomass was the reduction in nutrient load entrained in the biomass removed. An independent study contracted by the Wayland Surface Water Quality Committee in 2007 indicated Dudley Pond both has accumulated a high nutrient load in its thick sediments and receives a significant nutrient input, especially during stormwater runoff events. This input is likely from overfertilization in the surrounding watershed and septic system leakage.

In retrospect, the hand pulling effort should have begun in 2003, when the first milfoil sprigs were noticed. In order to have a real chance of control, given the exponential growth of milfoil, the 2004 effort should not have stopped at 40% of the population pulled. The 90% level or better should be the goal, given how fast milfoil proliferates.

Once the milfoil took hold, through various means volunteers were asked to help with removing fragments and hand pulling their own shores in waist deep water or shallower. Some volunteer snorklers helped. As has so often happened before, volunteer efforts are a dismal failure against a plant as aggressive as milfoil. Spotty efforts were attempted, but to no real efficacy.

SUMMARY AND LESSONS LEARNED

In the same year as a chemical treatment, vigilance through surface and underwater spotters is necessary to determine if there is any re-growth. Given the propensity to use as little chemical as possible, a complete kill of milfoil is not likely. In Dudley Pond, the presence of springs makes the long contact time necessary for fluridone to work more problematic. It is hypothesized that these springs were some of the areas that experienced the first sprig re-growth from not-quite-dead root balls.

Once new growth is spotted, call out the armies, be they paid divers, spotters, and shore waders, or volunteers. Professional paid help is best and most likely to succeed. Use surface spotters to mark the plants locations with bobbers attached to weights such as a short length of rebar. Use all means necessary to prevent any new growth from overwintering. It is this diver's experience that milfoil will generally die back to the root crown in the first winter, and not appear until the following year, after the water temperature exceeds 60 degrees F. If the same plant is left to overwinter again it generally does not die back to the root crown. Rather, it stays in existence throughout the winter, visible under the ice when there is no snow cover. In the spring, at ice-out, the plant that has gone through two winters or more is lurking just about 2 to 4 feet below the surface of the water, ready to sprout new growth as the temperature warms past 60 degrees.

Remove surface fragments on a regular basis. The milfoil accomplishes 25% of its spread through fragmentation. The other 75% is through stolen sub-sediment growth vegetative propagation, just like the runners of strawberries. (Source for 25%/75%: Journal of Aquatic Plant Management 35:pp63-68 1997 "Vegetative Spread of Eurasian Watermilfoil Colonies" by John D. Madsen and Dian H. Smith) The experience with volunteers in removing surface fragments has not been good. Volunteers tend to rake out their shore-front a couple times a season. Surface skimmers should be paid to remove fragments on the downwind side of the lake ANY time there is a reasonable wind. Otherwise these fragments tend to pile up in the shallows during the windy part of the day, then drift back out at night, when the winds usually subside. Fragments float a day or two, then sink to the bottom to re-root.

If it looks like the milfoil is winning, do whatever is within financial, manpower, and technical resources possible to stop the spread as early as possible. The middle of July is perhaps a late time to start. Divers can be more effective by pulling smaller plants rather than waiting until they have grown larger and require more time per plant to stuff into a netbag. If it is possible to obtain a suction harvester, that can aid in removal for patches where plants are closer together than about 3 feet between each plant. If the distance between plants is much greater than this, divers spend too much time moving the equipment from place to place, and working at odds with each other if it is a two-suction-hose model.

Weeding the Underwater Garden Lessons Learned for the Future:

Like weeding a garden, there are parallels in the lessons to be learned. As in any weeding operation, the smaller the weeds at the time of hand pulling, the less work required in pulling, bagging, and transporting them away from the garden. Diver hand pulling exhibits all the parallels to weeding a garden where certain desirable plants are to be spared and the weeds removed from among the desirables. The benefits of early removal include:

- Less developed root system is easier to pull.
- Less likely to leave an underground runner (called a sub-sediment "stolen" for milfoil's main method of self propagation) that can develop into a new plant.

Milfoil has very delicate stolens that are all but impossible to remove. From a search of the literature and personal contact with experts in the field, it is not yet clear to the author if the stolens left behind have enough DNA in a proper form to start a new plant. The other possibility is that no matter how hard a diver tries to clear out the entire root system, if even a little bit of the root crown is left behind a new plant may grow. This seems to be borne out by the observation that when a previously pulled established milfoil area (milfoil plants only a couple feet apart before hand pulling) is revisited a few weeks later, many tiny milfoil plants are observed sprouting from the sediment. Pulling the milfoil as early as possible, before it grows large enough to send out stolens for vegetative propagation, is one of the most important actions to be taken to enable long term control of many years with minimum diver effort. This author has witnessed and heard of anecdotally, several lakes in New England that are at a diver-managed condition where a couple divers spend a couple weeks a year patrolling and searching for new milfoil growth , pulling just a few plants to a few thousand plants in a year, but no more than that. In other words, they have not experienced the explosive exponential growth seen in Dudley Pond in 2004-2007 because many thousands of plants had to be left behind each year.

- Less biomass above ground means it is much easier to bag the weeds. When milfoil first erupts from the sediment it is a single stem. A diver can fit more than 250 of these easily into a net bag. After one year of growth, a milfoil plant usually has 12 to 20 stems per root ball. Vegetative propagation in a nutrient rich pond like Dudley Pond can mean a dozen daughter plants have begun with their own root balls. After one winter and through a second growing season a milfoil plant usually achieves 30 to 50 stems per plant. This plant can over winter in the second winter, without die-back to the root crown like most first-winter plants, and be visible one to four feet below the surface on ice-out. It is ready to spring into growth and reach the surface by early May. Attempting to pull a plant like this takes a large amount of diver time per plant. At times a diver has to put one or both knees down on the sediment and pull hard to remove this size plant. That usually creates a number of fragments because of fin and water motion, with the plant already having many of its parts ready to break loose on the slightest movement from wind, fish, or a diver. It also led to the observation mentioned in the body of this report that divers were working against a “wall of milfoil” in 2006. Divers may only be able to fit less than 60 of this size plant into a net bag before it is so full that literally no more can be stuffed into the bag. Further, due to the buoyancy of this biomass of milfoil a diver has to wear extra weights and pull the bag downward to be able to stuff plants into it. A bag this full can weigh upwards of a hundred pounds wet weight and makes for very tired divers and surface help who lug these bags to shore to dump them.
- If the goal is to remove biomass, diver hand pulling is not an effective means to do so. In 2007, once it was clear the battle was completely lost to hand pulling, harvesters were brought in. Big iron (self contained dedicated harvesting apparatus) and little iron (boat mounted detachable) harvesters were used. They removed biomass measured in the tens of tons. In 2007, a total of 32 tons was removed by harvesting. This author personally tested hand pulling after a fresh

cut was made, and estimated that diver productivity in hand pulling was at least 75% more productive after a harvester passed by. This is due to the evenness of the plant length to be pulled, and due to spending less time stuffing long stems of milfoil into a net bag to ensure fragments do not escape. Fin kicks are less likely to result in fragments being let loose in the lake as well.

- As in gardening, vigilance and diligence, vigilance and diligence, are the watchwords. Volunteers and dilettantes do not serve this purpose well at all. From 13 years of observing and diving, seeing some success stories such as at Wachusett Reservoir where milfoil is kept under control by annual vigilance and diligence, observing Dudley Pond go out of control three times, requiring the use of chemicals on this author's watch, volunteers and under funded efforts do not work to keep the garden in a controlled weed condition for more than a couple years.
- Snorklers do work in water generally less than six feet deep, which can cover a majority of the milfoil growth areas in certain lake bathymetry such as Dudley Pond. An expert snorkler is just about as productive as a diver in these conditions. This was tested in side by side comparisons of the amount of milfoil pulled by a snorkler working alongside a scuba diver.
- Shore waders can reach down to the bottom in thigh deep water to remove milfoil into a net bag. CAUTION: walking waders in swimsuits and wearing rubber fisherman's waders can get stuck in deep mud and drown before they can pull their legs out of the muck. Bottom conditions are very variable in New England due to the glacial till and overlay of soft organic sediments. Walking around a sandy point, one can take the next step into several feet thick bottom ooze that sucks at one's feet. Kayakers and canoeists can hand pull in a similar fashion to waders by reaching down and grasping the base of the plant. A similar caution goes for jumping out of a canoe into soft ooze that can suck at one's feet and prevent gasping air if one fell over while attempting to extract their feet. This is another reason to pay for professional help.