National Partners Measuring Success Pilot Project Initiative

Evaluation of Pesticide Management Practices on Golf Courses in the reduction of Pesticide Residues introduced into Surface Water Systems

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Roy Meyer[1], Lisa Crowning[2] and Deborah Smith-Fiola[2]

Project Coordinator: Roy Meyer, Research Scientist 1

New Jersey Department of Environmental Protection
Pesticide Control Program
Station Plaza 4
22 S. Clinton Avenue, 3rd floor
P.O. Box 411
Trenton, NJ 08625-0411

1 New Jersey Department of Environmental Protection, Pesticide Control Program
2 Cook College, Rutgers University, Rutgers Cooperative Extension of Ocean County

Introduction

Pesticides represent a major category of nonpoint source pollution. Golf courses, due to their visibility and desire for esthetic playing areas, are areas where the use of pesticides leads to the presumption of environmental contamination. These golf courses are therefore prone to examination regarding their management practices. The essential element for acceptance of Best Management Practices (BMPs) for golf courses is a demonstration of their effectiveness. This project seeks to examine pesticide residues exiting treated areas of the golf course after the introduction of appropriate BMPs.

The Pesticide Control Program, New Jersey Department of Environmental Protection (PCP, NJDEP) conducted a Golf Course Pesticide Monitoring program during the past six years. This project provides insight into the frequency and levels at which pesticide residues are detected in the surface water system of golf courses. The residues were targeted in a weekly sampling program conducted jointly by the Pesticide Control Program and the Rutgers Cooperative Extension of Ocean County. This program examined surface water both on the cooperating course and in those areas of entry into the watershed. Concurrent with the sampling program, the Rutgers Cooperative Extension of Ocean County (RCE) evaluated existing BMPs as well as the current course situation and developed recommendations regarding the adoption of BMPs specific to that course. The monitoring of the targeted pesticide residues provided an accurate assessment of the impact of BMPs on nonpoint source pollution by allowing a comparison with the data previously acquired during the previous monitoring program.

Resulting residues from golf course-related applications were greatly reduced as compared to previous sampling results. The majority of pesticide residues detected appeared related more to either past pesticide applications or current applications in the surrounding watershed area. The results of this project support the promotion of IPM (Integrated Pest Management) and BPM approaches on golf courses as demonstrated by the resulting reductions in pesticide use and pesticide movement from treated areas. This approach reduces the need for extensive monitoring following the adoption of IPM and BPM approaches and allows a more focused monitoring program.

The Pesticide Control Program, New Jersey Department of Environmental Protection provided oversight for the project. The experience gained during the six years of the Golf Course Pesticide Monitoring Project will be employed in the design, execution and interpretation of this project. Research Scientist Roy Meyer was the project manager, assisted by Environmental Specialist Linda Walsh and Research Scientist Curt Brown. The PCP Pesticide Laboratory (Supervising Chemist Ed Reilly and Research Scientist Randy Barbiero) conducted sample analysis following NJDEP, PCP pesticide residue analysis protocols.

The Rutgers Cooperative Extension of Ocean County currently operates an IPM program for Landscape Integrated Pest Management. RCE Extension Agent for Pest Management Deborah Smith-Fiola directed the evaluation of both any available BMPs as well as those currently in place on the cooperating golf course. Program Associate Lisa Crowning provided constant on-site coordination of the sampling effort as well as identification and assessment of the BMPs

currently in use. Additional duties included maintenance of schedules and equipment, sample storage and transport, and, when needed, sample collection.

Students from Georgian Court College (Lakewood, New Jersey) conducted the majority of the weekly sampling events. Brenda Consentino, Tina Saltalamacchia, Audrey McGough, and Lisa Chandler took part in the project because of their interest in the environmental science field; all four students are pursuing a bachelor's degree in biology. Georgian Court faculty advisors Michael Gross and Louise Wooten facilitated the integration of the weekly sampling into the student's course work requirements. Unfortunately, the students did not receive credits towards their degree for this effort as originally intended. Should similar projects be conducted in the future, funds in the project budget should be set up to purchase credits directly for the participating students. This would provide the necessary link to insure the active and continued participation of the students, thereby strengthening their commitment. Similar partnerships with the faculty and students could lead to expansion to other environmental contaminates of interest within the watershed, opening opportunities for the evaluation of BMPs in other settings.

Ocean County Golf Course at Atlantis in Little Egg Harbor, a county-operated course, has participated over the past five years in the Pesticide Control Program Golf Course Pesticide Monitoring project. Barry Cox, the course superintendent, was eager to take part in the project, particularly the BMP evaluation aspects. Both course management and the Ocean County Board of Freeholders are committed to reducing the dependence upon pesticide use. Ultimately, the individual golf course superintendent is the best source regarding both the pest pressures and the response measures on any given course. These response measures include not just the pesticide applications but all forms of management related to pest infestations.

Sampling

Samples were obtained from surface water in and around the Atlantis Golf Course on a weekly basis. Four monitoring sites were established: two sites at ponds within the golf course and two sites on the canal/stream flowing through the golf course.

Site #1 (Pond 15) is a self contained pond adjacent to the 15th green. Before the construction of the golf course, this farm pond served as the "pig pond." Run-off from the surrounding golf course area (13th, 14th, 15th & 16th holes) enters the pond routinely.

Site #2 (Pond 6) is an aerated pond fed from surrounding bogs as well as run-off from the surrounding golf course area (holes 4, 5, 6 & 7). It is presumed that at one time, the pond was part of the natural water system running from the bogs to Barnegat Bay. The run-off potential is high due to the severe slope from the 4th green, 5th tee, fairway and green, and 6th tee and fairway. The slope from the 6th tee (behind the pond) also contributes significantly to the residue loading.

Of interest in this area of the course is the beginning of the canal leading to Barnegat Bay. This canal is an expansion of the existing stream system and may have been used to transport cranberries and other agricultural products to the Tuckerton seaport. Presently, the only physical connection between Pond 6 and the canal is a runoff culvert leading from the right of the 6th

green into the canal. According to the course superintendent, little movement of water has occurred over the past few years. The culvert was checked in detail by NJDEP staff before the initiation of the project and checked during each sampling event. The culvert was uniformly dry.

Site #3 (Pond 17) is an aerated pond on the stream located between the fairways of the 11th and 17th holes. It is influenced by runoff from treated areas on both sides of the pond (11th fairway and green, 12th, 13th and 16th holes, and 17th tee and green to the northeast; 8th, 9th and 10th hole, 11th tee, 17th green, and the 18th hole to the southwest). There is no influence on the stream system before this point

The PCP sampled three different sites during 1994 through 1996 (Sites listed previously as Sites #1, #2 and #3. Three fungicides were detected during the sixteen surface water-sampling events during the monitoring period: metalaxyl, triadimenol and vinclozlin. Products containing metalaxyl and vinclozlin were applied during the three-year period. While no triadimenol was used on the course, triadimefon is reduced in environmental settings to triadimenol, accounting for triadimenol detections. Results from that project are presented in the following table describing 1994-96 monitoring program results.

1994-96 monitoring program results						
Sampling Location	**Metalaxyl** (Mean)	No. Detections / Range	**Vinclozlin** (Mean)	No. Detections / Range	**Triadimenol** (Mean)	No. Detections / Range
Site #1 (Pond 15)	5.51 ug/l	6 0.91 – 11.6 ug/l	0.56 ug/l	3 0.03 – 1.25 ug/l	4.46 ug/l	7 1.01 – 9.82 ug/l
Site #2 (Pond 6)	0.26 ug/l	4 0.008 – 0.5 ug/l	0.26 ug/l	3 0.004 – 0.7 ug/l	ND	
Site #3 (Pond 17)	1.54 ug/l	4 0.058 – 5.66 ug/l	3.0 ug/l	2 0.16 – 5.83 ug/l	1.83 ug/l	1 1.83 ug/l

Site #4 (Radio Road Bridge) is an access point to the stream approximately equal distance from Site #2 and Site #3. There is no influence from golf course operations before this point. A housing development on the northern bank of the stream represents the only influence. This site was chosen primarily because of access from Radio Road. The banks on both sides of the stream are steep and the wooded undergrowth extends nearly to the bank, making access difficult.

Samples were collected weekly at each site from April 14 to October 14, 1999. The 28 weeks represent an additional week of sampling, compared to the original proposal. This was done in order to capture the entire application season that was influenced by draught conditions throughout July and August. NJDEP and Pesticide Control Program routine sampling procedures were followed throughout the project. All cooperators were trained and overseen by Pesticide Control Program staff in order to ensure quality control / quality assurance measures.

Pesticide Control Program staff obtained additional quality control samples throughout the sampling program.

The Pesticide Residue Laboratory, PCP, NJDEP analyzed all surface water samples. The analysis was conducted using the Gas Chromatograph / Ion Trap Detector Mass Spectrometer (GC/ITD). This system is routinely capable of detecting up to 200 pesticide residues in water at levels from 0.65 ppb (part per billion) down to 0.07 ppb. The majority of pesticides currently employed on golf courses as well in agriculture and home use can be detected by this system. The samples were extracted and analyzed per the laboratory Standard Operating Procedures. The list of previously detected pesticides during the initial monitoring of the Atlantis golf course served as the starting point for the targeted residues. The list was then expanded using the overall list of detections coupled with the pesticides currently in use on the golf course. The targeted list served as a reference in no way limited the analytical procedures. As the use information from the current season became available, the targeted residue list was amended to reflect the pesticides actually applied to the course.

The pesticide use on Atlantis Golf Course during the period 1995 to 1999 reflected the weather and pest pressure. Pounds of active ingredient peaked at nearly 700 pounds active ingredient (a.i.) in 1995 with a low of just less than 300 pounds a.i. in 1996. On average, 472 pounds a.i. were applied annually; this is happens to be a typical amount a.i. for the average New Jersey golf course. As is the case on most New Jersey golf courses, the vast majority of the pesticides applied were fungicides for control on a variety of turf diseases. In 1999, just over 550 pounds a.i. were applied to the golf course, not counting pesticides applied for mosquito control. Under normal circumstances, the golf course does not apply mosquito control pesticides. Due to weather conditions and concern regarding the possible spread of the West Nile Virus into the New Jersey coastal region, in 1999 the golf course applied malathion and resmethrin (under the direction of the Ocean County Mosquito Commission).

Ocean County Golf Course at Atlantis Golf
Pesticides Applied - 1999

Common Name /Active Ingredient	Trade Name	Chemical Class / Type	Amount active ingredient (a.i.) applied during 1999 season
Golf Course (Turf Management) Pesticides			
Carbaryl	*Sevin*	Carbamate Insecticide	20 pounds
Chlorothalonil	*Daconil, Twosome*	Chloronitrile Fungicide	257.25 pounds
Chlorpyrifos	*Dursban*	Organophosphate Insecticide	4 pounds
Cyproconazole	*Sentinel*	Triazole Fungicide	6.7 pounds
Fenarimol	*Twosome*	Pyrimidine Fungicide	24.75 pounds
Metalaxyl	*Subdue*	Acylalanine Fungicide	7 pounds
Propamocarb	*Banol*	Carbamate Fungicide	204 pounds
Propiconazole	*Banner maxx*	Triazole Fungicide	2.6 pounds
Thiophanate-methyl	*Cavalier*	Carbamate, Benzimidazole Fungicide	10 pounds
Trichlorfon	*Proxol*	Organophosphate, Organochlorine Insecticide	18 pounds
Vinclozolin	*Touché*	Dichloranilide Fungicide	8.3 pounds
Mosquito Control Pesticides			
Malathion	*Fyfanon*	Organophosphate Insecticide	12 gallons
Resmethrin	*Scourge*	Pyrethroid Insecticide	6 gallons

Results

1999 monitoring program results – Site #1 (Pond 15)			
Pesticide Residue Detected	**Mean Residue***	**Number of Detections**	**Range**
Metalaxyl	0.28 ug / l	12	Trace – 0.6 ug/l
Dichlorvos	0.34 ug/l	1	0.34 ug/l
Methoxychlor	0.26 ug/l	3	0.096 – 0.37 ug/l
Malathion	1.02 ug/l	1	1.02 ug/l
4,4'-DDD	0.011 ug/l	3	Trace – 0.016 ug/l
4,4'-DDE	0.021 ug/l	21	Trace – 0.06 ug/l
4,4'-DDT	0.005 ug/l	1	0.005 ug/l

Trace detections not included in calculation of mean

1999 monitoring program results – Site #2 (Pond 6)			
Pesticide Residue Detected	**Mean Residue***	**Number of Detections**	**Range**
Metalaxyl	0.026 ug / l	4	0.013 – 0.038 ug/l
Dichlorvos	0.009 ug/l	2	0.005 – 0.013 ug/l
Aldrin	0.047 ug/l	1	0.047 ug/l
Malathion	0.185 ug/l	12	0.009 – 0.67 ug/l
4,4'-DDD	0.019 ug/l	20	Trace – 0.075 ug/l
4,4'-DDE	0.028 ug/l	20	Trace – 0.04 ug/l
4,4'-DDT	0.014 ug/l	2	0.006 – 0.021 ug/l

Trace detections not included in calculation of mean

1999 monitoring program results – Site #3 (Pond 17)			
Pesticide Residue Detected	**Mean Residue***	**Number of Detections**	**Range**
Chlorothalonil	0.028 ug / l	2	0.009 – 0.046 ug/l
Malathion	0.071 ug/l	10	Trace – 0.22 ug/l
4,4'-DDD	0.024 ug/l	11	Trace – 0.083 ug/l
4,4'-DDE	0.013 ug/l	5	Trace – 0.023 ug/l
4,4'-DDT	0.81 ug/l	1	0.81 ug/l

Trace detections not included in calculation of mean

1999 monitoring program results – Site #4 (Radio Road)			
Pesticide Residue Detected	**Mean Residue***	**Number of Detections**	**Range**
Malathion	0.02 ug/l	4	0.014 – 0.032 ug/l
Metolachlor	0.0034 ug/l	5	0.002 – 0.005 ug/l
4,4'-DDE	0.005 ug/l	2	Trace – 0.005 ug/l
4,4'-DDT	Trace	1	Trace

Trace detections not included in calculation of mean

Ocean County Golf Course at Atlantis Golf
Detected Pesticide Residues

Common Name /Active Ingredient/ Trade Name	Typical use on golf course	Chemical Class / Type	Amount active ingredient (a.i.) applied during 1999 season	Explanation / Notes
Metalaxyl *Subdue*	Controls soil borne diseases	Acylalanine Fungicide	7 pounds	Metalaxyl is very water-soluble and moves with any surface water movement. In the previous monitoring program, metalaxyl was detected in 46% of all surface water samples. Use at Atlantis greatly reduced since 1994.
Dichlorvos (Trichlorfon) *(Proxol)*	Contact, stomach poison acting as fumigant, insecticide	Organophosphate Insecticide	None (18 pounds)	Trichlorfon degrades environmentally to dichlorvos.
Chlorothalonil *Daconil, Twosome*	Controls soil borne diseases	Chloronitrile Fungicide	257.25 pounds	Most frequently used fungicide on New Jersey golf courses; infrequently detected in surface water. Relatively persistent in the environment, it tends to bind to organic material. Movement into surface water due to particulates moving with surface water runoff.
Metolachlor *Dual*	Preemergence and preplant selective weed control	Herbicide	None	Very rarely used on New Jersey golf courses. Detections at Radio Road location apparently due to upstream use for vegetation clearance before housing construction.
Malathion *Fyfanon*	Controls sucking, chewing insects	Organophosphate Insecticide	12 gallons (for mosquito control)	Used by county mosquito commission during summer of 1999 for adult mosquito control. Areas around ponds and streams are traditional mosquito breeding grounds.
Methoxychlor	Controls sucking, chewing insects	Organochlorine Insecticide	None	While no methoxychlor was used on the golf course, it has been used in pesticide formulations with malathion. Its relatively short half-life would argue against the methoxychlor being residual from previous application seasons. No alternative source of methoxychlor was identified in the area.
Aldrin	Contact poison	Organochlorine Insecticide	None	Residual from previous uses for control of soil-dwelling insects.
4,4'-DDT	Contact poison	Organochlorine Insecticide	None	Residual from previous uses for control of soil-dwelling insects. Unusual to be detected in surface water; likely bound to particulates moving with surface water runoff.
4,4'-DDE		Degradation product of DDT	None	Residual from previous uses for control of soil-dwelling insects.
4,4'-DDD (TDE)		Degradation product of DDT	None	Residual from previous uses for control of soil-dwelling insects.

Evaluation of Monitoring Results at the Ocean County Golf Course at Atlantis

The results from the 1999 weekly monitoring of the Ocean County Golf Course at Atlantis are very encouraging. The majority of the pesticide residues detected were not associated with the routine insect and disease control measures employed on the course. The detection of residues in the two ponds contained within the course is consistent with what has been found on other golf courses in New Jersey. The trend to direct water movement into ponds contained on the course allows for the reuse of water and a reduction of pesticide residue movement.

Unexpectedly, weather conditions, particularly rainfall, did not appear to influence residue detections. This is probably due to the drought conditions present during the summer of 1999. Irrigation was necessary to maintain the turf as any kind of playable surface.

The frequency and concentration of pesticide residues detected has decreased since the initial monitoring effort. Metalaxyl, the only pesticide detected during both sampling events, dropped from a peak of 11.6 ug/l to a peak of 0.6 ug/l, a fifty-fold decrease. This is due in part to a significant reduction in use of *Subdue* in response to the initial detections, an excellent example of a Best Management Practice at work. It is important to note that the total amount of pesticides used, as measured in pounds of active ingredient used, has not significantly changed over the past five years. What has changed is the overall management of the course. The pesticide products selected, particularly *Banol*, *Daconil* and *Twosome*, generally tend not to migrate from the site of application. A comparison of the levels detected with environmental levels of concern provides an excellent frame of reference. These maximum levels detected, compared to the lowest aquatic reference level, indicate a minimal level of impact resulting from these applications.

Comparison of Detections of Pesticides currently in use with Environmental Levels of Concern			
Pesticide	**Maximum Level Detected (ppb)**	**Environmental Level (ppm)**	**Ratio**
Chlorothalonil	0.46 ug/l	0.25 mg/l /96 hr LC_{50} – rainbow trout	1 / 543
Dichlorvos	0.34 ug/l	0.9 mg/l /96 hr LC_{50} – bluegill	1 / 2647
Malathion	1.02 ug/l	0.064 mg/l /96 hr LC_{50} – walleye	1 / 63
Metalaxyl	0.6 ug/l	>100 mg/l /96 hr LC_{50} – rainbow trout, carp, bluegill	1 / 166,667
Methoxychlor	0.37 ug/l	0.017 mg/l /96 hr LC_{50} – Atlantic salmon	1 / 46
Metolachlor	0.005 ug/l	2 mg/l /96 hr	

		LC_{50} – rainbow trout	1 / 400,000

Evaluation of Best Management Practices on the Ocean County Golf Course at Atlantis

The major aspect of Rutgers Cooperative Extension of Ocean County's role in this grant has been to evaluate the best management practices ("BMP's") of the Ocean County Golf Course at Atlantis and make recommendations as to their betterment and implementation.

Through interviews with Atlantis Golf Course Superintendent, quite a few best management practices have been identified at Atlantis. Those already implemented are based on the strong technical knowledge of the Superintendent and his desire for continuing education. The Superintendents' knowledge of plant material and appropriate insect and disease control are excellent. From an IPM context, the course is monitored daily and insect/disease activity is treated promptly, often using pest thresholds. The BMP's are used in context with the ultimate "playability" of the golf course.

Atlantis Golf Course presently exceeds by nearly 50% its original capacity for players. The resulting stress caused by overplay is carefully balanced by the superintendent.

Evidence that BMPs are followed can be found by the abundance of wildlife on the course; Canada geese make use of the ponds, which contain painted turtles, snapping turtles, and Koi fish. Deer enter the course every morning and evening. Purple Martins make use of the houses provided. Signs proclaiming the water's edge as "Environmentally Sensitive - Keep Off" ensure a safe habitat for wildlife. Composting of grass clippings and core plugs ensures a natural recycling of materials.

Overall Best Management Practices currently in place at Atlantis Golf Course include:

A. CULTURAL MANAGEMENT OF TURFGRASS

Healthy turf is less prone to attack by insect and disease pests. Horticultural management to improve turf health include:

- aeration to reduce compaction and improve turfgrass health (with core aerators, high-pressure hydrating aerators, and a new 'Verti-drain aerator');
- raising mowing heights to better manage drought stress; root pruning of close-proximity trees to sensitive turf areas (resulting in less competition for available moisture);
- thinning surrounding wooded areas (to increase air circulation on the course);
- accurately following soil test recommendations to ensure turfgrass health;
- closely managing fertilizer regimes (including the incorporation of composted turf plugs and OceanGro fertilizer from bio-solids).
- Clippings are returned to the turf.
- Irrigation is set on timers for optimal water usage
- Mowing heights are based on turfgrass type, turf usage, season, and conditions.
- Turf is syringed during summer heat, as needed, in order to reduce heat stress.

Cultural pest control tactics are used as an IPM alternative to pesticide treatments as much as is feasible. For instance, if a turfgrass can outgrow the disease problem (based on turf type, location, weather pattern, and fertility level), then the superintendent may wait and not treat a disease with a pesticide. If the disease will run its course quickly and the season permits quick re-seeding of a confined area, the superintendent may allow the disease to run its course and then re-seed.

Selection of proven turf types and varieties proven to perform best at the various mow heights and watering regimes offered at the course. For example, a zoysiagrass tee is maintained for play during the summer months. Seeding mixtures are changed to ensure least susceptible turf to repeat pathogens based on historical problems

To improve soil moisture holding capacity, OceanGro biosolid fertilizer is used also as a soil amendment. Topdressing is also performed regularly, which also maintains soil microbial activity.

B. RUNOFF WATER MANAGEMENT

The golf course is gently sloped, with no apparent erosion or need for critical stabilization.
Re-seeding is performed on a regular basis on specific areas.
Mulching is used on ornamental beds, and maintained at the recommended 3” level.
Buffer zones (burms) are maintained around ponds in the form of native vegetation.
Pesticide treatments are timed to decrease likelihood of leaching from weather or irrigation.

C. PESTICIDE HANDLING

Pesticides are used according to label directions, mixed only when needed, and selected based on low leaching potential. Employees comply with worker protection standards. Pesticides are not stockpiled, but purchased on an as needed basis, from the county bid list

Pesticides are stored, mixed, and rinsed according to state DEP regulations. Separate buildings are provided with wash stations and protective clothing; lockers and showers are provided; warning signs are apparent. Mix/rinse stations ensure proper capture and recycle capabilities. Proper disposal of unused portions of pesticides and empty containers is apparent and in conjunction with the county hazard waste disposal program.

Pesticide rates are based on university recommendations and label directions. Fertilization rates vary according to need, e.g. fairways vs. tees vs. rough

Pesticide storage appears according to local, state, and federal guidelines and regulations.
Basic pesticide record keeping is prepared as per DEP regulations
Data is kept on a computer spreadsheet

D. PESTICIDE MANAGEMENT (IPM practices)

Turf areas (i.e. greens, tees, fairways, roughs) are monitored for potential insect, disease and weed problems on a daily basis

Monitoring for chinch bugs employs “flushing” detergent technique for counts

Indicator plants used to determine weeds and soil conditions for applying pre-emergent herbicides

Use of a weather station on a consistent basis to forecast disease potential

Hands-on education of employees where time permits, providing multiple “eyes-on” monitoring for potential turfgrass problems.

Environmental factors are monitored that affect the progression of disease and insect such as weather patterns, season, stress level of turf, species of turf, fertility level of turf, initial severity, type of turf initially affected and proximity to finer turfgrasses

Disease/insect potentials are factored against quantity of damage and rate of progression of damage, evaluated against the cost of treatment vs. cost of replacement of turf. For example, Anthracnose of annual bluegrass is not treated; leafspot and dollar spot in a concise area of the rough are not treated. Established threshold levels determine the final management practice.

Threshold levels for disease and insects, in conjunction with spray determinations are used to evaluate what and when to apply, with *Pythium* blight having the least tolerance of the course (threshold of 0), and Anthracnose, snow mold, dollar spot, cut worms and chinch bugs having the most tolerance (thresholds of 3 and 4), with brown patch and grubs falling in between.

Insect management of biting mosquitoes and green flies is necessary. Treatments applied following monitoring and thresholds reached of bite counts.

Existing record keeping: Pesticide use on the course is recorded on a monthly basis.

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Foiliar analysis for pathogens is performed regularly. The use of a light microscope with a 400x lens facilitates the diagnosis of turf diseases by direct identification of spores. Turf can also be cultured in-house. The use of a weather station further facilitates prediction of disease outbreak conditions.

One disease, Pythium blight, has the potential to kill turf within 24 hours. Disease prediction kits are used to closely monitor outbreak conditions. If criteria are met, blanket sprays of a specific fungicide are used to prevent widespread loss due to *Pythium*.

Rotation of chemical classes, for example, a rotation of an IGR (Mach2) with a systemic (Merit) to prevent over-usage of any one chemical family.

Use of “trade tricks” to augment pesticide usage; i.e. for the control of cutworms, Sevin (carbaryl) is applied as a granule in the evening, as the dew activates the pesticide. Since the cutworms feed on or near the surface of the turf, a higher percentage is killed than if the pesticide was applied during the day.

Herbicides are rarely used, due to good cultural practices. A growing problem is the weed Nutsedge due to the Canada goose population. Where seen, it is either physically removed by hand and the area reseeded, or spot-treated with a non-selective herbicide.

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BMP Areas of improvement suggested for Atlantis Golf Course:

(Note: as part of the evaluation of pesticide usage, historical data from 3 years back (to 1996) was used to determine long-term and over-lap use of certain pesticide classes and formulations).

Blanket sprays for preventative measures are not consistent with IPM philosophy; however accountability for a playable and aesthetically pleasing golf course every day of the season for paying customers must also be factored in. The Atlantis golf course has met many BMP's and is to be complimented. The primary area needing improvement is record keeping. Although the Superintendent has an innate ability to determine pest thresholds and quantify damage, these observations must be recorded. Such records will be useful in order for his crew to learn and future management.

Current pesticide records lack entries noting the target pest, exact location(s), population levels and percent damage at the time of application to encourage spot treatments. Additionally, a means to quantify the percent damage seen should be recorded. A more complete form and examples of monitoring maps were given to Atlantis to use in order to quantify threshold levels and identify actual pest and location. This type of historical data becomes important in the future management of the course as well as the immediate needs of the research project.

Use of a map for each hole will help quantify damage as well as give visual record of where problems actually occurred.

Use of a tape recorder if paper forms prove to be tedious.

Monitoring and recording pest damage on a grid basis will allow for confident spot treatment and reduction of overall pesticide use.

Recording pesticide use is currently on a monthly basis, although RCE of OC would like to see this information on a weekly basis to better participate in the BMP suggestions.

Records ideally are computerized to allow for analysis of date

Regular monthly rotation of chemical families when using pesticides, e.g. Subdue rotated with Alliete. Including new chemical families, e.g. IGR's, naturalites.

Evaluate use of anti-backflow devises on hoses, calibration of equipment

Communication with the County Soil Conservation district for soils mapping of the course, to determine highly permeable soils, soils with poor absorptive capacity

IPM techniques worth trying:

Alternate spray techniques when a pest is suspected

Targeting and modifying potential pest overwintering sites; breeding areas, refuge.

Pitfall traps for trapping surface dwelling insect pests

Use of Plant phenology to determine pest activity levels. Planting indicator plants on/near the course to facilitate use of this tactic.

Use of degree-day models to predict pest activity.

Use of biological controls, particularly beneficial nematodes for grub control and B.t. for caterpillars (sod webworm).

Communication with the county mosquito commission for a monitoring inspection of mosquito breeding sites, followed by treatment with B.t. dunks

Cultural management

Routine soil sampling is recommended. Tees, roughs, and greens to be sampled separately. Irrigation water sampling also recommended periodically.

Use of zeolites/hydrogels to further improve soil moisture holding capacity could be considered, according to the golf course budget. These may be particularly useful in areas reseeded during hot, dry conditions.

Evaluate if berms would be effective in preventing potential pesticide runoff around ponds

Prioritizing time (and funding) for networking with other professionals, in-service training opportunities, and continuing education in IPM is desirable.

An overall evaluation of BMP's at Atlantis Golf Course reveals that the superintendent has done an excellent job in incorporating a majority of BMP's at this site. Considering that 1999 was a severe drought year, he has managed the course with environmental as well as financial restraints in a superb fashion. The following chart lists the BMP's currently performed (+) as well as those suggested. Note that the majority of suggested BMP's are in depth practices used in advanced IPM programs. Some BMP's have areas that could be improved over existing management practices.

Name of BMP	Existing use = (+) / Suggested adoption = (--)
Managing Pesticide Runoff	--
Irrigation Water Quality	+
Runoff Water Management	+
Pesticide Use	+
Pesticide Applications	+/--
Pesticide Storage	+
Soil Testing	--
Soil Culture	+
Fertility Management	+/--
Pesticide Records	+/--
Turf Culture	+
Diagnostic Techniques	+
IPM monitoring	+/--
IPM control tactics	+/--
Evaluation	+/--

Conclusions

The results from the 1999 weekly monitoring of the Ocean County Golf Course at Atlantis are very encouraging. The majority of the pesticide residues detected were not associated with the routine insect and disease control measures employed on the course. The detection of residues in the two ponds contained within the course is consistent with what has been found on other golf courses in New Jersey. The trend to direct water movement into ponds contained on the course allows for the reuse of water and a reduction of pesticide residue movement.

The frequency and concentration of pesticide residues detected has decreased since the initial monitoring effort. Metalaxyl, the only pesticide detected during both sampling events, dropped from a peak of 11.6 ug/l to a peak of 0.6 ug/l, a fifty-fold decrease. The mean detected level fell from 2.88 ug/l to 0.2 ug/l, an order of magnitude reduction. During the 1994-96 monitoring, 29% (4/14) of the detections were found in the receiving stream. During the 1999 monitoring, none of the detections of metalaxyl (0/16) were found in the receiving stream. This is due in part to a significant reduction in use of *Subdue* in response to the initial detections, an excellent example of a Best Management Practice at work.

It is important to note that the total amount of pesticides used, as measured in pounds of active ingredient used, has not significantly changed over the past five years. What has changed is the overall management of the course. The pesticide products selected, particularly *Banol*, *Daconil* and *Twosome*, generally tend not to migrate from the site of application. A comparison of the levels detected with environmental levels of concern provides an excellent frame of reference. These maximum levels detected, compared to the lowest aquatic reference level, indicate a minimal level of impact resulting from these applications.

The evaluation by Rutgers Cooperative Extension of Ocean County (RCE) of the current best management practices ("BMP's") of the Ocean County Golf Course at Atlantis has identified a broad range of BMP's in place. These include many practices in the four general areas of BMP's for golf courses: 1) Cultural management of turfgrass, 2) Runoff water management, 3) Pesticide handling, and 4) Pesticide use management (i.e., IPM practices). These existing BMP's were examined for effectiveness and possible improvement.

In addition, new and/or advanced practices were recommended for adoption by the golf course. Of the fifteen areas examined by the RCE, only two (management of pesticide runoff and routine soil testing) were not currently being utilized on the course. Another six areas showed room for improvement and refinement. Seven areas (47%) were in use and deemed effective and appropriate as being practiced on the course. Thirteen of fifteen practices (87%) are in place on the course, an outstanding record.

This evaluation provides an excellent gauge by which the operations on other golf courses can be judged. The BMP evaluation procedure provides a tool whereby existing practices can be improved or new practices can be implemented.