Freshwater crops

Aquafarm produces fish, compost and vegetables

By Kim Asch
Free Press Staff Writer

It's a humid 90-plus degrees inside the South Burlington greenhouse, and Erik Wells, farmer of the future, is soaked with sweat.

His discomfort does nothing to dampen his enthusiasm for showing off the pilot project he predicts will soon grow into a viable year-round business raising a "crop" that thrives in this kind of heat: tilapia, a tropical fish prized for its mild, flaky white meat.

Right now the "farm," a series of heated, water-filled tubs stocked with hundreds of fingerlings, occupies a small corner of the 7,000-square-foot greenhouse just down the lane from the Magic Hat Brewing Company. Suspended above the tubs are racks overflowing with lush vegetation — plump tomatoes and leafy basil — whose roots feed on nutrients from the water circulating through this closed ecosystem, rather than soil. This aquafarm is a self-sustaining, integrated environment in which waste produced as part of one process is used to fuel another.

Photos by **GLENN RUSSELL**, *Free Press*

Abigail Beck (right) and Erik Wells feed worms to the tilapia fish raised at a "farm" in South Burlington where shrimp, mushrooms, worms and vegetables feed each other.

Oyster mushrooms (above) and tilapia (right) are part of the cycle of plants living off fish and vice versa.

"Everything is interconnected, each has a role," says Wells, 27, who has a bachelor's degree in plant soil science and environmental science from the University of Vermont. He is working with his mentor John Todd, a UVM professor and founder of Ocean Arks International, the non-profit organization that oversees this project. "Everything is designed to eliminate waste, produce healthy food sources and clean water."

Think shin bone connected to the ankle bone. The tilapia give off ammonia that is converted by a biofilter into nitrates that feed the hydroponically grown vegetables. The plants, in turn, purify the water while their roots supply it with oxygen. Meanwhile, fresh water shrimp thrive at the bottom of a clarifying tub, feeding on tilapia excrement and uneaten feed cleansed from the water as it circulates through the system.

There's more.

In another part of the greenhouse, oyster mushrooms sprout from plastic bags filled with straw and spent grain supplied by Magic Hat. After the gourmet fungi are harvested and sold to local restaurants and grocers for as much as $6.50 per pound wholesale, the by-products are put through an onsite vermicomposting system where they're broken down and enriched by the worms as they feed and propagate.

The compost is used as a planting medium. In the summer, it's more profitable to sell the special worm casting compost to gardeners. In the winter, when fresh produce is in short supply, Ocean Arks will use the compost to grow and sell gourmet salad greens such as arugula and mesclun mix.

And guess what eats the worms? The tilapia, of course. Wells scoops up a handful of fat, writhing worms and sprinkles them over the top of the tilapia tub. A swarm of fish suddenly appears at the surface.

Tilapia are omnivorous but don't require high amounts of protein. A key aspect of this Ocean Arks project involves cutting back on the quantity of commercial feed typically used to raise tilapia by providing them with the worms and duckweed, a protein-rich plant that floats on the surface of the tub, to munch on. This not only reduces costs but makes good ecological sense, Wells explains, since commercial feed is comprised mostly of fish meal made by "robbing the ocean of a key component of the food chain."

In the South Burlington greenhouse, the project is still in its pilot phase. A number of environmental organizations have supported its research and development with grants, including $9,733 from the Sustainable Agriculture Research and Education program. The Intervale Foundation is also a collaborator. And the mushroom facet of the operation is supported by the Vermont Sustainable Jobs Fund.

Going forward, the plan is to expand to a production-scale operation in the eco-industrial park to be built in Burlington's Intervale. There, a number of food processors, farms and greenhouses will use cheap heat provided by the hot water produced by the nearby McNeil power plant's cooling tower.

If all this sounds a bit futuristic — even farfetched — to the average consumer, it doesn't

See **TILAPIA**, *6C*

If you go

- **WHAT:** See Ocean Arks International's ecologically integrated tilapia farm in South Burlington for yourself. It's open to the public for free, self-guided tours.
- **WHEN:** Monday through Friday from 9 a.m. to 5 p.m.
- **CONTACT:** Call ahead to assure someone will be on site at 660-8094.
- **ALSO:** Hour-long guided, educational tours are available by appointment for groups of up to 25 at a cost of $50 per tour.
- **ONE-DAY TECHNICAL COURSE SEPT. 21:** Learn about many aspects of integrated agricultural production, including aquaculture, hydroponics, mushrooms, worm composting and winter produce. Cost: $65. Call Ryan Case at 860-0011 to reserve a spot or for a schedule of future workshops.


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New Living Machines
The scope of Dr. John Todd's Living Machines—miniature ecosystems partly used to treat wastewater while growing food—has been expanding beyond anyone's dreams.
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The Living Machine facility in South Burlington, Vermont, is home to a wide variety of plants and systems.

Six years ago, I had the opportunity to visit Findhorn, an alternative living community in northeast Scotland (see "Listening to the Angels," *The Growing Edge*, Volume 8, Number 2). One of the highlights of this trip was to see the first Living Machine in Europe transforming sewage into almost pure water.

According to Dr. John Todd, a pioneer in the realm of water restorative technologies, since my visit to Findhorn in 1996, the Living Machine system there has continued to be an outstanding success. "Like a great wine," he said, "it just keeps on getting better and better."

More recently, in January 2002, I traveled to South Burlington, Vermont, to write about another initiative undertaken by Todd and Ocean Arks International called the "South Burlington Living Machine Project." This project is setting to prove the economic viability of an integrated ecological food production system. Todd wanted Ocean Arks to have more of a focus on food production, so he brought in Erik Wells to spearhead an operation that will convert an ecological Living Machine wastewater system into an integrated agricultural model that will lead to new sustainable enterprises. "Erik is one of the bright new lights here at Ocean Arks," said Todd. "We are both working closely together on a concept that will eventually expand into eco-industrial parks to become new enterprise zones for dealing with waste. It's the idea of using ecological integration to bring communities together to create new economies."

OCEAN ARKS

OLD PROBLEMS NEW LIVING MACHINES

Text and photos by Michael Spillane

From Waste to Food Production

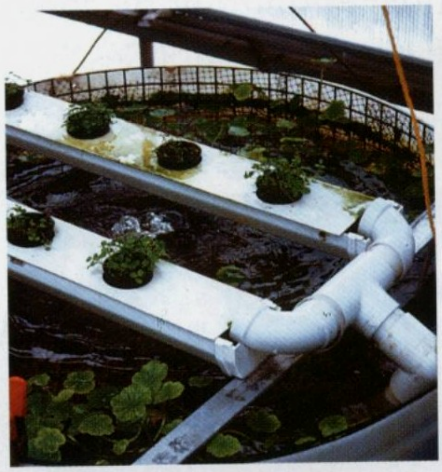
The mission statement for this new project in South Burlington is: "To develop ecologically and economically sustainable systems by converting underutilized biological resources to high quality foods and other value-added agricultural products." The existing facility includes a 7,000-square-foot greenhouse, an ecological wastewater treatment system, and a testing lab. Originally, the facility was used to process municipal wastewater, absorbing around 80,000 gallons a day from a conventional treatment center nearby. This Living Machine was an experimental project funded by the Environmental Protection Agency. It lasted five years and ended two years ago when the final project reports were submitted. "From a research perspective it was a very successful project," said Wells, "but when the funding ended there wasn't a strong enough initiative to keep the system operating due to increased maintenance costs and things of that nature. It was a scale issue, really. The facility was treating about 10 percent of the total waste coming into the conventional plant—of which there are two for the city of South Burlington. For smaller municipalities, it was proven to be very effective."

Smaller-scale Living Machine wastewater treatment systems are still operating in some of the top ski resorts throughout the state of Vermont. At Smugglers' Notch, about 45 minutes from Burlington, a Living Machine system processes 40,000 gallons of wastewater a day. The fluid flows through a network of lagoons and is then diverted through the Living Machine as part of the treatment process. According to Seth Miller, the environmentalist for the resort, despite some ongoing problems with maintenance, the Living Machine system has proven to be very effective and has been in operation now for two years. The system has become an attraction for guests staying at the resort with tours offered to explain how the process works.

Although the original project was established solely to process wastewater, the new initiative will integrate many agricultural and horticultural activities, spawning a wide variety of local food production systems that are both ecologically and economically sustainable. These include aquaculture, vermiculture, hydroponics, mushroom production, and more. The new venture will be a testing ground and pilot project that, once operating fully, will be replicated in local communities on a more commercially viable scale. "We have to be able to compete in the marketplace," said Wells, "and develop to a scale that really makes an impact in the food market, providing year-round quality foods for local communities in northern climates."

The Living Details

The transition from wastewater treatment to integrated agricultural food production facility only really started in 2001. However, they're already converting a variety of underutilized raw materials into high-quality foods and other agricultural products. The main organic by-products from local food manufacturers and farms used in the system include spent grain from a local brewery and chicken bedding from an organic poultry operation owned by Wells. "Mushrooms are grown on these by-products, harvested, then the material is put through the vermicomposting system to produce worms, which are then fed to the fish in the aquaculture tanks and sold to local bait stores or to home users for composting," he said.



Left: **Hydroponic growing systems have been integrated into the Living Machine concept. The goal is to combine several different agricultural methods in the process of cleaning up wastewater. The resulting system concept will not only produce ornamental plants and food crops, but also serve as a method of municipal or personal water treatment.**

Nothing is wasted in this complex cycle. Waste produced as part of one process will be used to fuel another. Everything is designed to eliminate waste, produce healthy food sources, and clean water. "The raw materials used in the system—spent grains and animal bedding—are more often than not a liability to the farms and breweries that produce them," said Wells. "We convert this waste material into nutritious salad greens and high-end mushrooms. Excess material is also sold as rich, value-added worm-casting compost, ideal for lawns and gardens. We are hoping to purchase an automated vermicomposter that will greatly increase the scale of our material of between 2–15 tons a day. We can then sell this material to local farmers for spreading on their fields."

Opposite page, right: **The facility in South Burlington is a proving ground for various Living Machine concepts. The staff is experimenting with different setups and crops to see how far they can push the envelope of integrated agricultural production and wastewater treatment.**

Aquaculture, Aquaponics, and Hydroponics

Their recirculating aquaculture systems produce high-quality fish in an ecologically sound, self-sustaining environment that doesn't require commercial feed containing fishmeal derived from the ocean or intensive systems for dealing with waste products. "We do not consider using fishmeal for feeding the fish a sustainable practice," said Wells. "We'd rather use grain-based or vegetation-based feeds from our own aquaculture system."

Tilapia, yellow perch, and baitfish are the main species produced in the aquaculture tanks. There are two species of baitfish that are being developed as a source of native, ecologically grown species. Many baitfish imported to Vermont from outside areas carry the threat of bringing foreign pathogens with them or becoming invasive and contaminating natural waterways. Native species are a better option for maintaining a balanced, sustainable system. The baitfish also provide a valuable function in the system by helping control detritus buildup and main-

taining water quality. These scavenging fish feed lower on the food chain so they tend to devour a lot of the waste in the system. Rainbow trout is another species under consideration for the aquaculture project. The species, however, requires a high-protein diet so the formulation of sustainable feeds supplemented with the right balance of amendments presents another challenge for the team.

Around 400 small tilapia swarm close to the surface of the heated aquaponic tank. Watercress in a small nutrient film technique type of hydroponic system rides over the top of the tank. "Last summer as part of a test marketing project we harvested and sold between 400 to 500 pounds of tilapia filets to customers," said Wells. "We're looking at growing the watercress on a much larger scale but at this point it's still a demonstration project."

The nutrient-rich water from the aquaculture tanks is used to feed vegetable and horticultural crops that are grown in both hydroponic systems and a variety of compost-based materials, such as a combination of compost and coir. The solid waste from the tanks is used to feed the worms in the vermicomposting system, which in turn are fed back to the fish. The heat and moisture rising off the surface of the culture tanks nurtures the salad greens that are grown on top in winter. "It's really a combination of organic soil or media-based systems and hydroponics," said Wells. "We're still working on the production scales and marketing of the baitfish and yellow perch. We sold all our tilapia last summer at $8 a pound. The average wholesale price for tilapia filets is somewhere between $3–4 a pound. So we're doing quite well at a retail level."

The yellow perch are kept in a tank with a temperature of around 45°F. They feed on a combination of worms and freshwater shrimp that are harvested from the larger culture tanks. Higher temperatures are needed for tilapia. Forced hot air and an automated climate control system help maintain the right conditions for the plants and fish. Daily monitoring of the aquaculture tanks is carried out along with weekly water quality testing. Records are kept to maintain optimum conditions in the facility.

Mushroom Production

The mushrooms are grown in a small room where the temperature and humidity are controlled. Around 50–100 pounds of oyster mushrooms are harvested a week and sold to a local food store. Other mushroom varieties, such as crimini and portobello, are being developed for production. "It's a high-end product," said Wells. "We're getting $6.50 a pound wholesale for our oyster mushrooms—the average wholesale price is around $3.70 a pound."

One of the advantageous aspects of growing mushrooms in the system is that the majority of spent grain used by farmers as a feed source isn't highly digestible to the animals, which can create serious problems. However, running this material through the mushroom system and letting the mushrooms colonize the grain and straw transforms some of the proteins in the material to a much higher level, generating a higher percentage of lysine—a highly attractive protein for livestock production. So the end product—the spent mushroom compost—after harvesting can then be used as a value-added feed for livestock. "There's great potential here with so many spin-offs in a variety of applications," said Wells. "It's advantageous to everyone and there's no pollution or harmful effects to the environment."

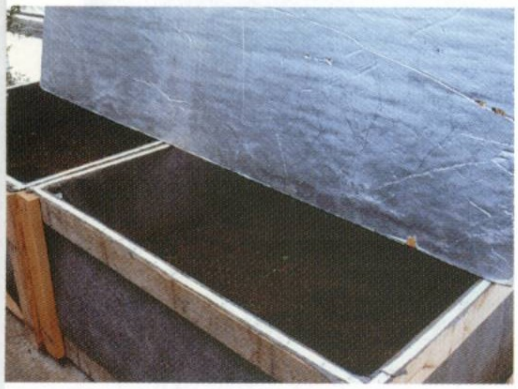
Above: **Erik Wells displays an oyster mushroom production bag. The mushrooms are produced using by-products from a local brewery and an organic poultry farm owned by Wells. The oyster mushrooms from the South Burlington facility are fetching well over the going rate on the market. Other mushroom varieties are currently being considered for production.** ***Left:*** **Anywhere from 50 to 100 pounds of mushrooms are grown in an environmentally controlled room at the facility.**

The mushrooms are grown in bags in a combination of straw and spent grain. The vegetative form of the fungi start to colonize the bags after about 12 days in the incubation section of the grow room. As they develop, they're moved into a second room with a climate set to simulate the conditions that exist on the forest floor, with fractured light and a moist, warm environment. The cropping cycle is around 4–5 weeks from incubation to harvesting.

A positively pressured filtered air system in the grow room ensures that there aren't any problems with airborne contaminants in the early stages of growth. Fruit flies can be a problem, since they're attracted to the scent of the mushrooms. The rooms are sealed tightly and pest and disease management controls are closely adhered to at all times.

Wells is looking at using a wood fiber bag that could be composted rather than the polyethylene bags that are currently used. As well as serving as a value-added feed supplement, the spent mushroom compost is put through the vermicomposting system for future use in salad green production.

The vermicomposting system has a variety of uses that are linked to the aquaculture tanks, the salad green production system, and the mushrooms. Chicken and animal bedding, spent grain, and mushroom compost is mixed together and fed to the worms in the compost bins. The worms are harvested, fed to the fish, or sold as bait or for composting. The spent compost is then recycled back through the system.



Above: **Vermicomposting is a valuable part of the integrated Living Machine process. The worms are fed a mixture of chicken bedding, spent grain, and mushroom compost.**

The Greenhouse

The greenhouse itself is a sanctuary for many interesting and exotic tropical plants, including giant calla lilies, banana plants, and different types of *Ficus*. The plants were installed as part of the original system, designed by a team of talented botanists who worked hard to create a beautiful flora that provided a functional role in the system as well as enjoyment for visitors. "The existing flora serves as a seedbed of plant material for other Ocean Arks wastewater projects," said Wells.

Below: **The worms thrive on a rich mixture of materials that eventually becomes valuable compost.**

"We have also started producing plant material for local businesses and landowners for ponds and water gardens. We are working with local garden centers, nurseries, and landscape companies to expand the market further and are selling potted houseplants and tropical patio plants."

Expanding the aquaponics operation, however, means that a lot of shifting around is necessary to be able to keep all the lush vegetation in place. With limited space to work, there's a need to increase the biodiversity of the system and at the same time maintain stability. Balance is critical in an operation that merges so many elements.

"We plan to use the space on and above certain tanks for the production of salad greens, cut flowers, and other crops," said Wells. "A main focus is to develop and perfect a system for using the vermicompost as a media for year-round production of salad greens. The plants would be irrigated by the nutrient-rich water from the culture tanks." The plans for the use of the facility are constantly developing as the possibilities for the operation reveal themselves. There's the possibility of a joint application between treating the wastewater produced by the brewery—just a few hundred yards from the greenhouse—and an integrated aquaculture system that would utilize the incoming wastes. The solids generated from the waste, for example, could be used as a protein source for feeding the fish. Diversification, ingenuity, and flexibility are key elements in the future of this project.

Each tank in the Living Machine system in the greenhouse is 14 feet deep and 14 feet across. The tanks go 10 feet below the surface so it's difficult to control the temperature of the tanks effectively due to surrounding groundwater. There are 18 tanks with a total fluid-holding capacity of 200,000 gallons.

There are two configurations of nine interconnected tanks. In the original wastewater treatment process, raw sewage would be pumped into tanks 1A and 1B and would then flow by gravity throughout the system. The first five tanks in the Living Machine configuration are open, aerobic environments that provide a lot of oxygen to the deep, spreading plant root mass. These roots provide a perfect habitat for a variety of bacteria, snails, protozoa, and zooplankton. Tank 6 is called the "clarifier," where solids settle out. Tanks 7, 8, and 9 are known as "ecological fluidized beds" that complete the water cleansing process. The tanks have been allowed to self-clean and are now being assessed for their future role in the integrated food production system. According to Wells, a somewhat outdated computer control system operates the ridge and side greenhouse vents and connects to the heating system.

A Living Education

Education plays an important role at Ocean Arks and the doors at the South Burlington Living Machine facility are always open to the public. There's at least one school tour a week, with groups ranging anywhere from university graduate stu-

dents to kindergarten classes and preschoolers. Everyone seems to be fascinated by the operation and visitors enjoy the plethora of plant species on display. Both processes of wastewater treatment and food production are explained to the public in a broad educational program.

"We're working closely with the University of Vermont as well," said Wells. "We have a number of students doing internships and work study programs. John teaches at the university and brings his classes here. I think we're fairly successful at communicating what it is we're doing." A full-time assistant and six work-study students help with the daily chores. "We have created a positive relationship with the university with a mutually beneficial arrangement with the students. We get some extra hands-on help around here and they receive a valuable educational experience in return. Being a nonprofit enterprise at this stage, we need all the help we can get. At some point in time, we will fully commercialize the operation, but we're not there yet." Funding for the project at the South Burlington facility is through Ocean Arks International and private grants specifically allocated to the project. "We are actively pursuing more funding so we can continue our work here. We feel we need about another year to reach the point where we will be fully independent."

Born and raised an hour outside South Burlington, Wells has been a good find for the Ocean Arks team in Vermont. With a passionate focus and entrepreneurial mind, he has the right blend of business sense, agricultural production knowledge, and ecological design know-how. A former student in Todd's first course on ecological design at the University of Vermont, he went on to earn his Bachelor of Science in Plant Soil Science and Environmental Science. Wells, who is 26, became interested in agriculture when he was attending college. Inspired by Todd's teachings, he worked on a number of organic vegetable farms before starting his own business producing pasture-raised organic poultry. After three years, he has turned his business into a successful enterprise. He started at the Ocean Arks South Burlington facility in June 2001.

"I must have made some sort of impression on John Todd," said Wells, "because last year, out of the blue, he called me up and asked if I would be interested in working on this new Ocean Arks initiative. My focus is on food production and organic agriculture and then tying that in to ecological design. I'm interested in the cutting-edge work that Ocean Arks is renowned for. Also, the business end of things is very important—merging business, agriculture, and ecological design to create a viable entity that is able to compete in the marketplace and also have a competitive advantage. I'm very excited about the fundamentals of ecology and the environmental benefits of growing and producing food this way. I am presently looking for a team to manage my organic poultry business so I can devote my time entirely to this project."

Future Developments

There is definitely a need for change in the world today—a serious reevaluation of how we live and function on the planet. Environmental destruction continues, groundwater is contaminated, habitats are lost, land is overdeveloped, greenhouse gas emissions increase, soil further erodes, and so on—all of which point toward a bleak future unless we initiate changes soon. Ocean Arks International is part of the solution by dealing with the problems we face today by developing new, sustainable technologies.

After years of debate and discussion, it appears that the construction of an integrated food production facility will begin in the near future on a 700-acre flood plain agricultural area of Burlington known as the Intervale. To demonstrate the principles of ecological integration and sustainable food production techniques, Ocean Arks has maintained a small-scale bioshelter at the Intervale for several years. The goal is to expand this facility from a demonstration project into a production-scale model. "This is an exciting new project that will utilize waste heat from a wood-fired power plant already operating at the Intervale," said Wells. "The plant produces wastewater at 95°F that passes through cooling towers. There are plans to build an eco-park that would include a number of food processors, farms, and greenhouses that would utilize this waste heat to produce a sustainable energy source shared by the tenants involved in the project. We are looking at the Intervale as the next likely development site for these technologies. We feel we can take the principles demonstrated here in South Burlington and use them on a much larger scale at the Intervale to produce highly desired foods and clean water." Ocean Arks is working with the Intervale Foundation, a nonprofit organization set up to oversee agricultural activities and explore the opportunities for using these sustainable technologies in the development of the area.

Like Wells, Todd is fired up about the new development and is eager to get rolling. "This ecological industrial park that's happening in Burlington is very important to me, right now," he said. "It's breaking ground this year so the plan is to have the waste heat from the power station integrated into the design of the park by the end of the year. Then it's full steam ahead . . . all wrapped up in one 7-acre site. It's also going to be a new laboratory for a new generation of students to fledge."

As well as the South Burlington Living Machine project and the Intervale eco-industrial park, Todd and his team at

Inventing Modern America

In December 2001, the Massachusetts Institute of Technology Press published a book entitled *Inventing Modern America—From the Microwave to the Mouse*, by David E. Brown. This book profiles 35 inventors who are cited as being key figures in the evolution of modern times. Along with such luminary figures as George Washington Carver, Henry Ford, Buckminster Fuller, and Paul MacCready, Dr. John Todd was cited as being a major influence on modern America. Todd was chosen for his development of water restorative technologies, such as those that are currently being used by Ocean Arks to treat polluted ecosystems. For more information about *Inventing Modern America*, see http://web.mit.edu/invent/www/ima/ or call the MIT Press at (617) 253-5646.

Ocean Arks are involved in a number of new initiatives around the globe. In South China, the first phase of a huge project to clean up 80 kilometers of canals has been started. Using Ocean Arks Restorer treatment technologies, the canals are being transformed into beautiful floating gardens (a Restorer is a floating structure that provides the substrate and foundation to support a diversity of life forms that become living, water-filtering ecosystems).

They're also going to continue their work in Hawaii. "We've just signed an agreement to do a new slaughterhouse facility in Hawaii," said Todd. "It's grown out of a small project we've had there for the last few years, experimenting with endangered plant species for water treatment."

In Maryland, Ocean Arks has just completed a large-scale water treatment project for Tyson Foods, Inc., processing a million gallons of effluent a day from their poultry processing operation. Other projects include installing small Restorers for a pond at the Maine summer home of former President George H. W. Bush and for the golf course at the Four Seasons Resort in Hawaii.

At the University of Vermont, Todd is looking into ways to integrate nature into building design, retrofitting buildings so they become living systems that remove toxins from the air. "Buildings need to have new partnerships with the natural world," said Todd. "We've been nibbling at the edges on this issue for a while and now it's time to step up to the plate." As well as turning buildings into sustainable living systems and cleaning up waterways with raft Restorer technologies, Todd's goal is to bring a level of seriousness to healthy food production to the urban environment.

"It's happening," he said, with an optimistic edge to his delivery. "Just look at *The Growing Edge* magazine. I think it's one of the most interesting examples of how things are moving. None of this is official agriculture at all, but it is happening despite official agriculture. It takes someone like you to write about all this. People then realize that these are not isolated phenomenon but rather signposts to the future."

Thanks, John.

Michael Spillane is a freelance writer presently based in Toronto and a regular contributor to The Growing Edge.

Resource

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