Appendix A: General Process Description and Specification for all Systems.

The TF Ecotech system is based on the following concepts which describe how microbes can convert wood and nutrients into invertebrates and fish. Consider wood in the form of dry wood chips, sticks, or saplings without leaves. For purposes of illustration we assume that a ton of dry weight wood contains 1,000 pounds of cellulose, 400 pounds of lignin, 400 pounds of hemicellulose, and 200 pounds of ash.

In an appropriate aquatic environment, and with at least one pound or more of nitrogen and at least 0.3 pounds or more of phosphorus, the microbes and invertebrates can convert 1,000 pounds of mostly cellulose and some hemicellulose and ash into 35 to 40 pounds of wet weight fish. The lignin and some of the hemicellulose can be extracted as a high energy residual suitable for renewable energy production. The remaining hemicellulose with minor amounts of cellulose and lignin can be combined with a residual microbial biomass to produce a potting soil, an organic fertilizer, or a soil amendment. This latter distribution depends on the amount of excess nitrogen and phosphorus are available in the process, either from the wood, or added to the aquatic environment as feed or other forms of nutrients.

The system itself will comprise the following structural elements:

Contained water volume, tank or pond, that is suitable for raising product aquatic organisms. These will usually be fish but may also be other aquatic vertebrates such as turtles or amphibians, or they may be various macroinvertebrates such as crustacea, mollusks, snails, etc. In this discussion we assume that the product animal will be a fish and that the containment unit will be a fish tank.

Submerged wood chip baskets which are contained in a mesh or screen structure that allows a microbial biomass and accompanying invertebrate populations to be exposed to direct contact with the product animal, fish.

Irrigated perched wood chip baskets that are usually placed above the tank such that water from the fish tank can be pumped to the top of the perched baskets and allowed to flow down through the wood chips so that it reenters the fish tank.

A reversible two part collector/selector unit that is usually a tank, tray, barrel or similar structure dived into two connected regions. Thus water containing settled solids from the fish tank will be pumped into the first zone of the collector/selector. Overflow from this first zone will flow by gravity into the second zone. Overflow from the second zone will flow or be pumped back into the fish tank. When the first zone is half full of settled solids flow will be stopped. The solids will be pumped out, and flow will be resumed but now it will go into what used to be the second zone. From there it will overflow into the former first zone and go back to the fish tank.

Multiple water pumps will be used to maintain water flow through various recycle loops within the system. Also a blower or air pump system will provide aeration to various locations within the system.

System Configuration:

The basic system structural elements will be arranged in a particular application to satisfy the following criteria.

Maximize the availability of screened wood chip basket surfaces for fish access.

Maintain a flow pattern throughout the system that allows for settling of solid fish wastes and biofloc in specific areas so that they can be efficiently removed by periodic pumping and sent to the collector/selector.

Allow for some water flow and invertebrate movement through the submerged wood chip baskets.

Allow for easy removal and replacement of submerged and irrigated wood chip baskets.

Allow for easy supplemental addition of wood chips to the submerged and irrigated wood chip baskets to maintain a constant wood chip inventory within the total system.

Biological Components:

Generally all of the biological organisms used in a given system will be native to the bioregion in which the system will operate. This will include the trees that provide the wood chips as well as the local fish that live in the areas' streams, lakes, or ocean. Once one or two product fish are chosen the search and selection of additional organisms will focus on what are the natural foods for the fish.

These will usually include the terrestrial earthworms and aquatic oligochaete worms found near or in the natural habitat for the fish. For freshwater systems crayfish, freshwater snails, and small minnows are useful. Local insects and insect larvae are also candidates if they are easy to cultivate and deliver to the system.

Process:

The process involves tracking the carbon (C), nitrogen (N), and phosphorus (P) elements as they enter, move through the recycle loops, and leave the system. It begins with the wood chips and whatever N and P is contained in the wood chips. This is then supplemented by an external source of nutrients. Often this will be a commercial fish feed designed for the product fish to be grown.

The fish will use the carbonaceous materials in the feed to provide the energy for the fish growth and assimilation of N and P into the body of the product fish. But this is not a very efficient process and a majority of the N and P consumed is excreted in both solid and liquid form.

There is not enough carbon in the excreted fish wastes to bioconvert the excreted N and P back into a microbial biomass. However, the wood chips provide the extra carbon needed to capture the excreted N and P and incorporate them back into a microbial biomass. This drives an additional food chain for more fish production.

Tracking the movement of the C, N, and P through a steady state operating system requires measuring or calculating the mass of each element that enters the system and when this occurs. Comparable measurements or calculations then describe the distribution function for each element in the various solid and liquid components of the system This will include the biological organisms, unused inputs such as the wood chip inventory, uneaten fish food, excreted wastes from fish and other organisms, non soluble suspended and settled solids, and total dissolved solids.

Finally, all C, N, and P that exits the system needs to be measured or calculated. This includes the elements in the product animals, the partially degraded residual wood chips, all harvested and removed settled solids, all dissolved and suspended C, N, and P in the system effluent, and all gaseous emissions. The latter will be almost all carbon dioxide. Other greenhouse gases such as nitrogen oxides, ammonia, reactive organic gases (eg. acetate), etc. should be absent and this can be verified when necessary or desirable.

Process control: For large systems this will comprise measuring water quality parameters such as temperature, Dissolved Oxygen, pH, ORP, salinity, conductivity, alkalinity, TDS, TSS, TVS, and chemical parameters such as TKN, Total Phosphorus, cBOD, COD, TAN, Nitrate, Nitrite, ammonium ion, and orthophosphate. Lignin, cellulose, and hemi cellulose concentrations in raw and residual wood chips will also be useful.

For small systems a basic pond water test kit for temperature, pH, salinity, ammonium ion, and ortho phosphate can suffice. DO is useful but not always necessary if excess aeration is supplied.

Process Control algorithms and procedures are available for individual applications. In general, we will use a feed for trout with a 3 to 1 N/P ratio. Then we will try to maintain a pH of 7.0 and an ammonium ion to orthophosphate ratio of 4 to 1 in the fish tank.

Harvesting:

Once a system is adequately populated with microorganisms and invertebrates it can be operated so that fish are removed in either a batch or intermittent steady state mode. When this occurs some of the wood chips will be removed as well.

Batch mode: A target fish size is selected and the free water volume (tank water volume minus the submerged chip basket volume) will be stocked with a given number and weight of small fish. This will be determined so that when the surviving fish (initial stocking minus expected mortality) reach the target fish size, the carrying capacity of the free water volume will be equal to some target fish biomass density. All fish will then be removed and some fraction of the submerged and irrigated wood chips may also be removed.

The system can then be recharged by bringing the wood chip inventory back to its initial state and restoring the microorganism and invertebrate populations to their earlier levels.

Intermittent steady state mode: This will be for a system that already has established microbial and invertebrate populations. A working number of fish will be stocked and allowed to grow. Some of these initially stocked fish will be harvested once they reach one of several targeted weights for marketed fish. A target maximum fish biomass density will be chosen and the initial stocking will be such that when the fish biomass density is first achieved, that there will be some fish that meet the smallest of the initial market target weights. Some of these fish will be harvested and the system will continue to operate until the maximum fish biomass density is again achieved. At that point some of those fish that now meet the second target market size will be removed.

This cycling will be repeated until all fish are removed from the system. The system then will be restored to its initial state and restocked for another sequence.

Some submerged wood chips will be harvested and removed from the system each time fish are harvested.

The alternating two zone solid collector / organism selector unit will receive the solid wastes collected from the fish raising zones. These solids will be distributed to one of the two selector tanks where the solids will settle out and invertebrate organisms will grow. The overflow will go to the second tank and then back into the main fish growing area. When one solids collection tank is half full the flow pattern will be reversed and the settled solids and invertebrate organisms pumped out of the first tank. The invertebrates will be fed to the fish and the solids will harvested to become an organic fertilizer or potting soil.

Chip harvesting:

The surface of the wood chips is where the initial microbial growth will occur. This is because the microbes need the energy in the wood chip to assimilate the N and P in the water and convert it into a microbial biomass. At the start of this process the composition of the wood chip is about 70 to 95 percent cellulose and hemi cellulose with 5 to 30 percent lignin. As the degradation of the wood chip continues the cellulose goes first and then the hemicellulose is attacked next, and this is accompanied by a decrease in efficiency and microbial growth rate at the surface. The wood chip surface becomes less desirable and microbial turnover and invertebrate predation reduce the microbial concentration at the chip surface.

We try to harvest the wood chips when the degradation has removed about half of the initial wood chip mass. The chip structure is still similar to that of the initial wood chip because its structure is mostly determined by the lignin which will not have been substantially degraded. It is however now much more porus so a simple washing or hosing of the chips will induce the invertebrates to leave, and most of the microbes to be removed from, the chip.

A version of the batch mode can employ some of the steady state harvesting procedures. In this version when the fish reach the target size they will have a total mass of X, but only only half of the fish will be removed. The remaining fish will have a total mass of X/2. They will be allowed to grow as before but when the total mass again reaches X, half of the remaining fish will be removed. This will continue until all fish have been removed. Wood chip removal and replacement will be as for the steady state mode.