III. PRODUCTION LIMITS

There are biological limits in the production pond or aquatic environment. Stocking densities and harvest yields are finite and determined by pond (environmental) carrying capacity. The availability of dissolved oxygen is the primary factor determining maximum pond biomass. Depending on temperature, salinity and atmospheric pressure, water can only hold a certain concentration of oxygen. As the overall weight or biomass of a farmed species increases in the culture pond, so does oxygen demand. When respiratory demand exceeds the rate of oxygen replacement from surface diffusion and photosynthesis, either aeration is employed or oxygen becomes depleted and the culture species suffocate.

The total biomass in production ponds is composed primarily of phytoplankton, zooplankton, the culture species and other micro-organisms (bacteria, fungi, etc.). Phytoplankton produce most of the oxygen consumed in the production pond through photosynthesis. But phytoplankton consume oxygen as well. The waste products (manure, uneaten feed and excreted ammonia) from the primary culture species release nitrogen and phosphorus (fertilizer) into the pond which stimulate the growth of phytoplankton. The nitrogenous wastes can be toxic to aquatic animals. However, when the phytoplankton population (or bloom) becomes too dense, nighttime oxygen consumption becomes greater than the rate of replacement from surface diffusion and photosynthesis. Production wastes cap harvest biomass by increasing phytoplankton growth beyond critical densities.

Phytoplankton productivity and biomass are measured indirectly as the chlorophyll a concentration (μg/l). Contrary to the popular maxim that "nutrients (e.g., phosphorus and nitrogen) are limiting" for plant (phytoplankton) growth, in heavily stocked or intensive, production ponds, light can be the limiting factor. The concentration of plants becomes so high (400-600 μg/L chlorophyll a) that light can not penetrate to any appreciable depth (Tucker, 1996). This limits photosynthetic oxygen production and primary productivity while respiration increases or continues unattenuated. When phytoplankton populations are sufficiently dense, even aeration will not maintain dissolved oxygen at concentrations acceptable for aquatic life. In addition to oxygen depletions, the off-flavors commonly associated with dense algal blooms will hamper production (i.e., unmarketable product).

IV. POND BIOMASS

From a commercial standpoint, it is easy to view the cash crop as being the only significant species in a production pond. As discussed previously, pond biomass consists of several aquatic life-forms, not the least of which are planktonic. Little empirical data exist about zooplankton productivity in aquaculture ponds (eutrophic waters) and even less practical information is available for predicting standing, zooplankton biomass. However, there is some knowledge about phytoplankton productivity, respiration and standing biomass in intensively farmed ponds (Boyd, 1982; Losordo, 1988; Piedrahita, 1991; Smith, 1991; Tucker, 1996). Boyd and Tucker (1995) reported that for every 1,000 kg of live channel catfish harvested, total phytoplankton productivity is 2,500 kg/ha dry weight or approximately 50,000 kg/ha wet weight. Each season the plankton biomass is lost when these organisms die, break down, and return to their basic components: water, carbon dioxide, nitrogen and phophorus.

On a dry weight basis, phytoplankton and zooplankton could easily account for almost half of the total, daily biomass in a culture pond. At harvest, there would be a standing biomass (dry weight) of approximately 900-1,000 kg/ha of plankton for 1,000 kg/ha (5,000 kg/ha wet weight) of channel catfish. Because of their smaller size and greater surface area to volume ratio, phytoplankton and zooplankton have significantly greater metabolic rates and therefore, much higher respiratory rates. In a commercial production pond, phytoplankton alone can consume greater than five times more oxygen per day than channel catfish (Table 3).

V. PLANKTON HARVEST

The most obvious way to increase the harvest biomass of a culture species is to lower oxygen demand by reducing plankton biomass. Greater oxygen availability would permit higher stocking densities and bigger yields. Plankton could be harvested either mechanically or biologically. Mechanical harvest would involve pumping water through filters and collecting the plankton retained. Because the mesh or screen size determines the size of the particle harvested, filter screen selection and placement would be critical. Screen mesh must be small enough to retain the size of plankton desired but large enough to allow smaller plankton and particles to pass through unobstructed. Larger particles such as zooplankton must be removed before filtering smaller particles like phytoplankton and minute zooplankton. Otherwise, the small mesh screens for phytoplankton would become clogged rapidly by the large zooplankton, and filtering would be disrupted. While mechanical harvest of plankton may be technologically feasible, it is likely that economic obstacles and the current lack of markets for plankton products would make this approach impractical.

TABLE 3
Daily Respiratory Oxygen Demand for Channel Catfish and Phytoplankton in an Intensive Production Pond.

Type	**DO (mg/L • day)**
Catfish[a]	3.5
Phytoplankton[b]	18

Adapted from Tucker (1996)
[a]Standing biomass = 5,000 kg/ha
[b]Chlorophyll a = 300 μg/L