PD/A CRSP Seventeenth Annual Technical Report

New Site Development and Characterization

Eighth Work Plan, Kenya Research 1 (8KR1)
Final Report

Karen Veverica
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

Jim Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

Bethuel Omolo
Kenya Fisheries Department
Sagana Fish Farm
Sagana, Kenya

Abstract

Site development and characterization activities for the new prime site at Sagana, Kenya, began on 31 March 1997. Major undertakings that were required to make the site suitable for CRSP research included modification of the existing ponds, refurbishment of the water quality laboratory, acquisition of suitable laboratory and farm supplies and equipment, installation of a weather monitoring and recording (datalogger) system, and acquisition of a new computer system and an appropriate four-wheel-drive vehicle. Pond and laboratory renovations proceeded rapidly, and the major portions of these tasks were complete by the end of September 1997. Four existing 4,000-m^2 production ponds were modified to create twelve 800-m^2 ponds of uniform size and shape for CRSP research. Extra soil from the pond renovation was used to make seven additional ponds, ranging from 800 m^2 to 1,500 m^2, which will be used as holding ponds, for fry production, or for activities requiring the use of hapas. Three of the extra ponds have dimensions appropriate for experimental work. Farm and laboratory supplies and equipment arrived at Sagana in September 1997. A Land Rover was purchased from the United Kingdom and shipped to Kenya on 1 July , becoming available for project use in mid-September. Installation of the weather monitoring system was begun at the end of November, and weather data were recorded beginning the first week of December. In addition, observations on pond soil and source water chemistry and annual weather patterns were undertaken to allow characterization of the site. Initial pond soil samples were collected in October 1997, and water samples for source water characterization were collected starting in October 1997. Weather data recording was begun in December 1997. Solar radiation, photosynthetically active radiation (PAR), precipitation, relative humidity, wind speed, and air temperature were recorded hourly. Four temperature probes were suspended in one pond (D6) to record pond temperature at depths of 5, 25, 50, and 75 cm as of April 1998. Preliminary analyses of pond soil samples indicate that they are mainly of the "black cotton soils" variety, high in 2:1-type clay minerals (70 to 90% clay), with cation exchange capacities typical for that type of soil (30 to 55 meq 100 g^{-1}), and pH values ranging from 5.4 to 7.5. Lime will be required to ensure that carbon is not limiting in fertilization experiments or during production cycles. Lime requirements of 5 to 10 t ha^{-1} have been calculated. The phosphorus adsorption capacity of these soils is quite high. Total alkalinity and total hardness levels of water provided to the Sagana ponds through the 2-km canal system are typically 10 to 20 mg l^{-1} as $CaCO_3$. Source water conductivity was measured at 0.05 mmho cm^{-1}. Detailed characterization of the pond soils and source waters for the Sagana station, as well as a summary of the first year's weather, are included in this report.

Introduction

Maintaining a PD/A CRSP research site in Africa preserves the global range and environmental and socioeconomic diversity of CRSP efforts, giving greater applicability of database and model achievements and providing benefits for people in all of the major regions of the world. Following the tragic events in Rwanda in 1994, including the loss of the research site and facility at Rwasave Fish Culture Station, it was necessary to select a new site to carry on CRSP research in the African region. During 1994 and 1995, several sites in eastern and southern Africa were evaluated, and Sagana Fish Farm was recommended as the most suitable for CRSP research. A Memorandum of Understanding (MOU) between Oregon State University (OSU) and the Fisheries Department (FD) of the Government of Kenya was negotiated in 1996 and signed in March 1997, establishing Sagana Fish Farm, Sagana, Kenya, as the focal point for CRSP activities in Africa.

The Kenya Research Group of the CRSP consists of researchers at Oregon State University (OSU), Auburn University (AU), the Fisheries Department (FD) of the Government of Kenya, and the University of Arkansas at Pine Bluff (UAPB). The Department of Fisheries and Wildlife of OSU serves as the lead US institution and coordinates all Kenya research activities. OSU and AU direct the research effort and other activities through a single on-site US researcher, who works closely with the Host Country Principal Investigator (PI) and Research

Associate (RA). In-country activities of UAPB (mainly socio-economic studies) are coordinated through OSU and the on-site researcher to ensure efficient use of facilities and coordination with the Host Country PI and RA. US and Kenyan PIs have met at least once each year since the beginning of the project to evaluate progress and to prepare work plan proposals and budgets.

In order to properly conduct CRSP research and related activities at Sagana, some features of the farm needed improvement, upgrading, or modification. Most notably, the existing ponds were too large for research and the existing chemistry laboratory was inadequately equipped for carrying out the full range of CRSP analyses. Lab supplies and equipment previously used at the site in Rwanda had been completely lost and needed to be replaced. Characterization of the pond soils and the source water of the new site was needed to provide a basis for comparison with other sites and for proper analysis of experimental results.

More efficient management strategies developed through research conducted at Sagana will benefit fish farmers in Kenya, and resulting increases in fish production will partially offset the high demand for this product. Kenyan fish farmers, extension workers, and consumers will thus be the initial beneficiaries of this effort. As research continues and regional efforts are increased, fish farmers, extension workers, and planning officials throughout the region will also benefit from improved management strategies and increased production. Ultimately, all users of global CRSP models and data will benefit.

METHODS AND MATERIALS

The objectives of this activity were to prepare the new site at Sagana for CRSP research and to characterize the site in terms of pond soil, source water chemistry, and climatic characteristics. Existing ponds were modified so that they would be of the appropriate size and shape for aquaculture research. The chemistry lab was upgraded, equipped, and supplied with reagents to become a functional laboratory capable of performing all CRSP analyses. Fish culture supplies were upgraded or increased sufficiently to handle the increased level of farm activity required for conducting CRSP research. A four-wheel-drive vehicle was purchased for site operation, and additional computer hardware and software were provided. Soil, water, and climate attributes were observed and monitored. Soil and water sampling was undertaken according to standard CRSP analytical methods, and a weather monitoring station similar to that in use at other CRSP sites was assembled and put into use.

RESULTS AND DISCUSSION

Site development and characterization activities for the new prime site at Sagana, Kenya, began immediately upon arrival of the Africa Project's resident researcher, Karen Veverica, on 31 March 1997. Pond and laboratory renovations proceeded rapidly, and the major portions of these tasks were complete by the end of September 1997. Four existing 4,000-m^2 production ponds were modified to create twelve 800-m^2 ponds of uniform size and shape for CRSP research. Extra soil from the pond renovation was used to make seven additional ponds, ranging from 800 m^2 to 1,500 m^2, which will be used as holding ponds, for fry production, or for activities requiring the use of hapas. Three of the extra ponds have dimensions appropriate for experimental work. Farm and laboratory supplies and equipment, including a new desktop computer, laboratory instruments, and seines, were shipped from the US on 30 June and arrived at Sagana on 3 September 1997. A Land Rover was purchased from the United Kingdom and shipped to Kenya on 1 July, becoming available for project use in mid-September. The weather monitoring system was installed at the end of November and the recording of weather data was begun the first week of December.

With these changes, Sagana Fish Farm now has sufficient pond space of appropriate sizes and shapes for conducting pond research; adequate supplies and equipment for operating the farm; a well-equipped laboratory capable of performing the necessary analyses; a good weather monitoring station; computing equipment appropriate for recording data, conducting statistical analyses, and writing reports; and an efficient, reliable vehicle for transportation. The lab can and does analyze water samples brought in by farmers, and training of station personnel continues so that they can correctly interpret the results of water analyses and make recommendations to farmers.

In addition, observations on pond soil and source water chemistry and annual weather patterns were undertaken to characterize the new site. Initial pond soil samples were collected in October 1997, and water samples for source water characterization were collected starting in October 1997. Weather data recording was begun in December 1997. Solar radiation, photosynthetically active radiation (PAR), precipitation, relative humidity, wind speed, and air temperature were recorded hourly. Four temperature probes were suspended in one pond (D6) to record pond temperature at depths of 5, 25, 50, and 75 cm as of April 1998.

Pond Soils

Analyses of pond soil samples indicate that they are mainly of the "black cotton soils" variety, high in 2:1 type clay minerals (70 to 90% clay), with cation exchange capacities typical for that type of soil (30 to 55 meq 100 g^{-1}), and pH values ranging from 5.4 to 7.5. Lime will be required to ensure that carbon is not limiting in fertilization experiments or during production cycles. Lime requirements have been calculated to be in the range of 5 to 10 t ha^{-1}. The phosphorus adsorption capacity of these soils is quite high.

Soil cores were collected from Sagana ponds as part of the Pond Soil Characteristics and Dynamics of Soil Organic Matter and Nutrients (8PDR1) study in September 1997 (Boyd et al., 1999). Although these samples will be used in long-term studies being undertaken by the soils group, they also provide information more fully characterizing Sagana's pond soils at the beginning of the CRSPs involvement there. Phosphorus concentrations were found to be low (0.03 to 0.07% total phosphorus and 13.39 to 17.34 ppm dilute acid extractable phosphorus), supporting our expectation that phosphorus adsorption capacities would be high. Carbon concentrations in these samples were in the 2 to 5% range, and carbon:nitrogen ratios were between 10 and 20. Concentrations of exchangeable bases were high, and soil pH values were in the near-neutral range (Boyd et al., 1999). Greater detail on the characteristics of these soil samples, including profile descriptions and comparisons with samples taken at other CRSP sites, are presented by Boyd et al. (1999).

Source Water Chemistry

Total alkalinity and total hardness levels of water provided to the Sagana ponds through the 2-km canal system are typically 10 to 20 mg l^{-1} as $CaCO_3$. Conductivity was measured at 0.05 mmho cm^{-1}.

Weather

Weather data recorded by earlier workers at Sagana from 1987 to 1992 indicated that average monthly air temperatures ranged from a July low of about 23.5°C to a high of about 29°C in March. Over this same period of time, average monthly sunshine ranged from about 110 h (August) to approximately 245 h (March). Monthly averages for rainfall were reported to range from lows of about 2.5 mm (February) and 4 to 5 mm (July to September) to highs of around 350 mm (April) and 230 mm (November), indicating that there are two rainy periods for the Sagana area (Vanlerberghe, pers. comm., 1996). Our observations during the first year of the CRSP presence at Sagana indicate that, for purposes of conducting "warm-season" or "cool-season" experiments, there is a short cool season from June to August, and that the remainder of the year should be considered warm.

Following is a brief summary of the weather patterns that were observed at Sagana during the PD/A CRSPs first year of experimental work there. Although site preparations were begun in late March 1997, installation of the weather monitoring system was not complete until late November. Detailed daily weather observations thus began on 26 November 1997. The data for this period of time (26 November 1997 through 26 November 1998) will be accessible at the CRSP Central Database by the end of 1999. The Internet address for the CRSP Database is <biosys.bre.orst.edu/crspdb/>.

Climate

A few remarks about the climate of the Sagana area will provide the setting for weather patterns observed at Sagana Fish Farm during the CRSPs first year there. Sagana is located in Kenya's central highlands region (Central Province) near the southern slopes of Mt. Kenya. It lies at an elevation of 1,230 m, and is very close to the equator, at latitude 0°39'S and longitude 37°12'E. An official climate class designation is apparently not available for Sagana, but at least two other locations in the central highlands have been classified as having Cw climates ("warm with dry winter") in the Köppen classification system, due to the relatively cool average temperatures observed there. Both nearby Embu (30 km ENE from Sagana, at an elevation of 1,493 m) and Nairobi (90 km S, at 1,791 m elevation) fall into this category. Their cool average temperatures are associated with their relatively high elevations.

Sagana's climate is unique relative to the climates of these other locations, however, being noticeably warmer than both Embu and Nairobi. Rainfall and temperature data collected by the CRSP during its first year of involvement at the site suggest that Sagana's climate would be classified as an Aw ("tropical wet and dry" or "tropical savanna") climate in the Köppen system. According to Lutgens and Tarbuck (1992), Aw and Cw climates have similar rainfall patterns and the Cw climates are simply cooler variants of Aw climates. The cooler temperature regimes of Cw climates are usually due to higher elevations. The temperature boundary between A and C climates is at 18°C; in A climates the average temperature of the coldest month is greater than 18°, whereas in C climates the average temperature of at least one month drops below 18° (Lutgens and Tarbuck, 1992). In this case, the warmer temperature regime of Sagana is apparently due to the fact that it lies in a relatively low spot in the highlands. At an elevation 561 m lower than that of Nairobi, Sagana has mean monthly temperatures that average approximately 3 to 4°C higher than those of Nairobi. Similarly, Sagana is 263 m lower than Embu, and this results in temperatures about 1 to 2°C higher at Sagana than at Embu. Both Embu and Nairobi have at least one month each year with an average temperature below 18°C, which puts them over the boundary into the Cw class. During the CRSPs first year in Sagana, there was no month with an average temperature lower than 18°C. Although the average temperature observed during July 1998 was just 18.3°C, which suggests that Sagana's climate might be very close to the boundary between the A and C classes, local residents described the 1997–1998 year as being cooler than average. If over the long term Sagana's coldest month averages above 18°C, as we suspect it does, then it indeed has an Aw climate. Climatic diagrams showing temperature and precipitation patterns for Sagana, Embu, and Nairobi are shown in Figure 1. It should be noted, however, that the diagram for Sagana reflects a single year's data rather than long-term data.

Although Sagana's climate (Aw) is warmer than the Cw climates of Embu and Nairobi, it is still characterized by having mean annual temperatures that are slightly lower and annual temperature ranges that are higher than those in the "wet tropics," i.e., in the Af and Am climates of the Köppen system. Annual temperatures in Aw climates can vary by up to 10°C, as compared with typical variations of less than 3°C in Af or Am climates (Lutgens and Tarbuck, 1992). Indeed, Sagana's variation in monthly temperatures through the CRSPs first year exhibited a range of approximately 4.1°C (Figure 1). For comparison, Figure 1 also includes a climatic diagram for Mbandaka, in the Democratic Republic of the Congo (formerly Coquilhatville, Zaire), which has an Af climate. Mbandaka's average monthly temperatures are approximately 2.5°C warmer than those at Sagana, and the annual temperature variation at Mbandaka is only about 1.3°C.

Sagana's Weather During the 1997–1998 Year

Most of the 1997–1998 year at Sagana was warm but not hot, with daily average temperatures ranging from 19 to 23°C. The warmest period was from February through April, and the highest daily maximum temperature observed was 30.69°C, recorded on 8 April 1998. There was a distinct cool season between June and August, with average temperatures ranging from 17 to 19°C during this time. However, the lowest daily minimum temperature was 12.12°C, recorded on 1 October 1998. This seasonal pattern at Sagana is apparent from the air temperature data shown in Figures 1 and 2 and summarized in Table 1. Low average air temperatures from June through August were the result of low daily maximum temperatures; daily minimum temperatures were fairly constant during this period (Figure 2). The low daily maxima were due to low solar radiation levels (Figures 3 and 4). Even though there was not much rain during this period (Figure 5), the skies were overcast much of the day.

Photosynthetically active radiation (PAR) is much higher at this site than at the Rwanda site, which is only 1.5° farther south in latitude. At Butare, Rwanda, PAR rarely measured greater than 35 Einsteins m^{-2} d^{-1}, and readings in the 20s were

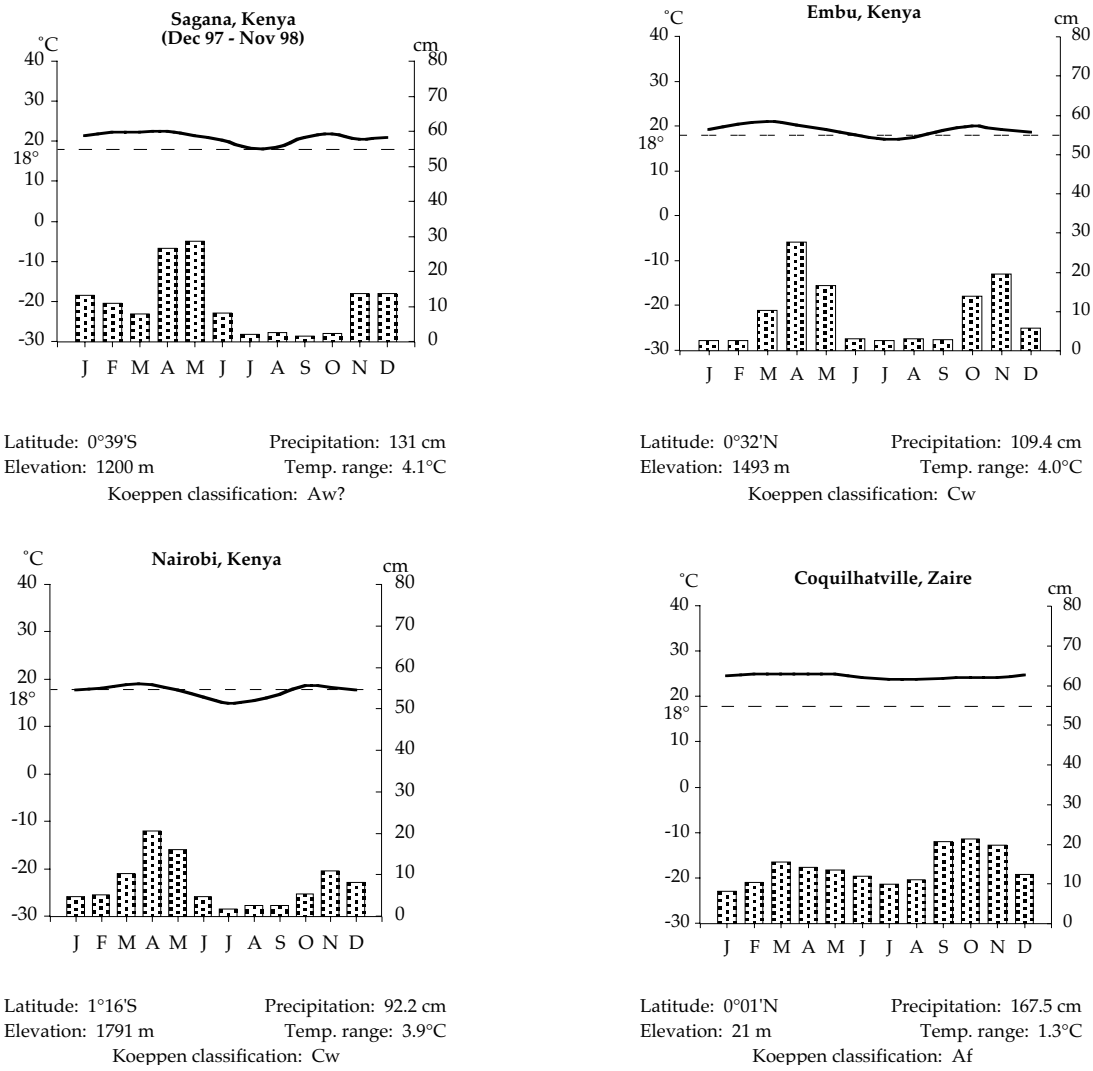

Figure 1. Climatic diagrams for four African sites located relatively close to the equator, including Sagana, Embu, and Nairobi, Kenya, and Coquilhatville, Zaire (now renamed Mbandaka, Democratic Republic of the Congo). In each diagram, the temperature scale is on the left and the precipitation scale is on the right. Vertical bars represent average monthly precipitation and curved lines represent average monthly temperatures. The dotted horizontal line at 18°C shows the temperature boundary between A and C climates. Note the narrow annual temperature ranges of the sites in Kenya (Aw and Cw climates), and the very narrow range at Coquilhatville (Af climate). Also note the similarity between the precipitation and temperature patterns of Sagana, Embu, and Nairobi (see text for discussion). Sagana data are from December 1997 to November 1998). Data for Nairobi and Coquilhatville are from Lutgens and Tarbuck (1992), and Embu data are from the WorldClimate website at <www.worldclimate.com/cgi-bin/grid.pl?gr=N00E037>.

Table 1. Approximate seasonal temperature ranges, in °C, at Sagana Fish Farm during the period from December 1997 through November 1998. Temperature ranges are from five-day running averages recorded by the datalogger system.

	Cool Season (June to August)	**Warm Season** (September to May)
Daily Minima	14–16	15–19
Daily Maxima	20–24	23–30
Daily Averages	17–19	19–23

more common. At Sagana, Rwanda-like readings are common in cool season, but during the rest of the year, values of 30 to 50 Einsteins m^{-2} d^{-1} are more common (Figure 3). The relationship between solar radiation as MJ m^{-2} d^{-1} and PAR (Einsteins m^{-2} d^{-1}) for the reporting period is shown in Figure 6.

In December 1997 and January and February 1998, temperatures were lower than usual, and rainfall was greater than usual. This was due to the El Niño rains, which started in October 1997 and continued into 1998 (Figure 5). Total rainfall for the interval from 26 November 1997 to 26 November 1998 was 1,385 mm, as compared with a total of 1,570 mm for 1997 and a 30-year average of 1,166 mm (Figure 5).

Evaporation was measured at the Ministry of Agriculture weather station, just behind the hatchery at the station. A rain gauge at the Ministry of Agriculture station was used in the evaporation calculations through August 1998, but the rain gauge was not functional from September on, with the result that no evaporation calculations could be made after 31 August 1998. During the 303 days that evaporation was measured, values ranged from 0 to 7.4 mm d^{-1}, with an average of 3.2 mm evaporation d^{-1}.

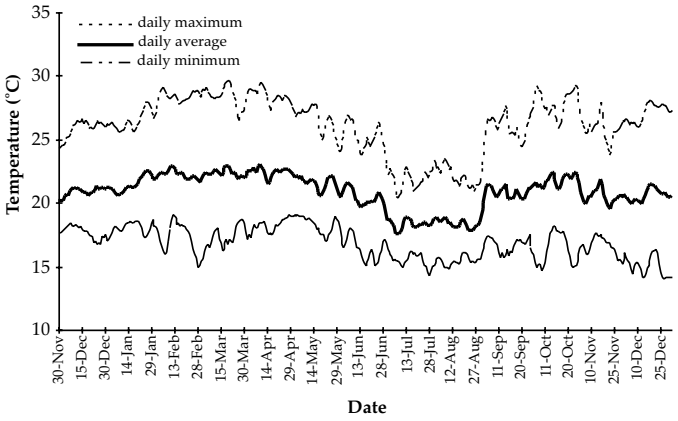

Figure 2. Five-day running averages of daily average, daily maximum, and daily minimum air temperatures at Sagana Fish Farm, Sagana, Kenya, between November 1997 and December 1998.

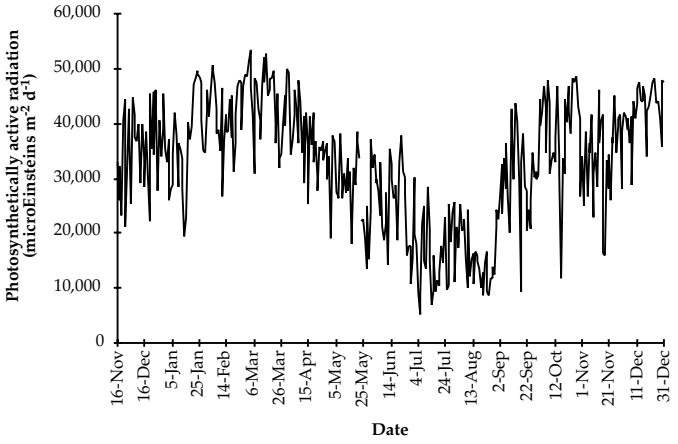

Figure 3. Photosynthetically active radiation (PAR) in microEinsteins m^{-2} d^{-1} for the period 26 November 1997 through 3 December 1998 at Sagana Fish Farm, Sagana, Kenya.

Because the weather station is situated directly on the pond banks, maximum humidity near 100% was observed every night except during intervals when the ponds were drained. Average daily humidity observations for the year are shown in Figure 7. Average monthly humidity ranged from a high of 79.12% in July to a low of 63.35% in October.

Daily mean wind speed was lowest during the cool season (Figure 8). During the rest of the year, wind speed was greatest in the late afternoon (between 1600 and 1800 hours) on bright sunny days. Ponds mixed well to a depth of about 50 cm on windy days. Dissolved oxygen levels at 75 cm depth increased slightly after 1600 hours on windy days. Data on pond water temperatures and stratification will be presented elsewhere (Veverica et al., 2000).

ANTICIPATED BENEFITS

Establishing a new prime research site in Africa maintains the global range of environmental and socioeconomic diversity of the overall PD/A CRSP research effort. Developing the pond area at Sagana Fish Farm to include a complete set of research ponds of an appropriate size allows for proper replication of experimental treatments, and ensuring that the ponds are of uniform size and shape lends validity to results of research

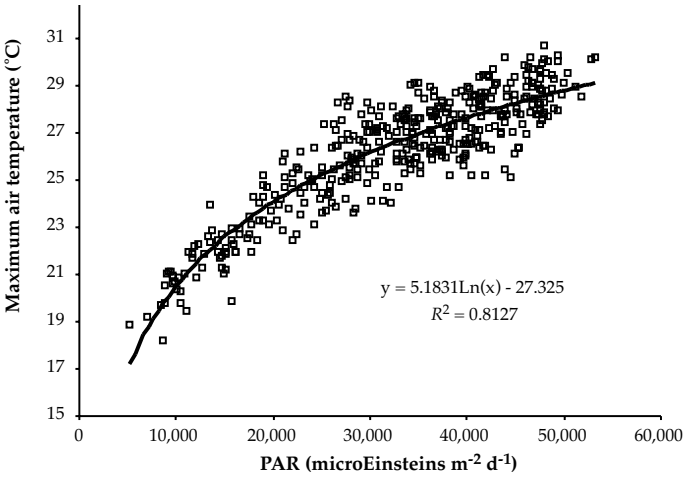

Figure 4. Relationship between maximum air temperature (°C) and photosynthetically active radiation (PAR), in microEinsteins m^{-2} d^{-1}, at Sagana Fish Farm during the period 26 November 1997 through 3 December 1998.

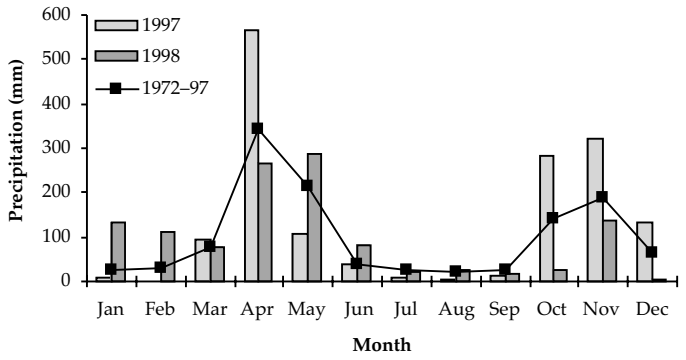

Figure 5. Monthly precipitation at Sagana Fish Farm for 1997, 1998, and the 25-year average for the period from 1972 to 1997.

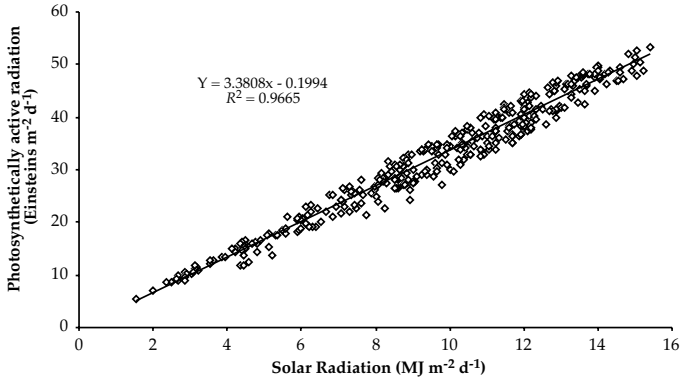

Figure 6. The relationship between solar radiation as MJ m^{-2} d^{-1} and photosynthetically active radiation (PAR), in Einsteins m^{-2} d^{-1}, at Sagana Fish Farm during the period 26 November 1997 through 3 December 1998.

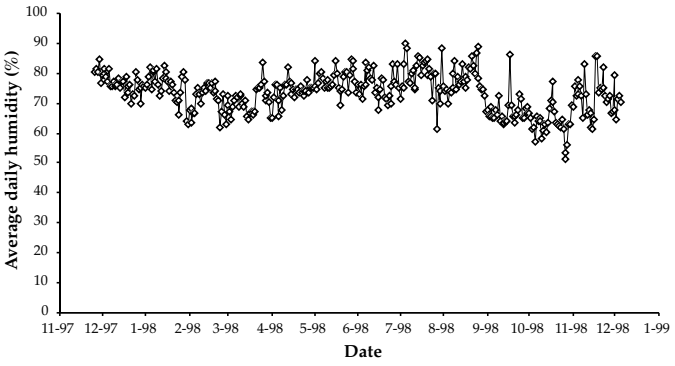

Figure 7. Average daily humidity observations at Sagana Fish Farm, Sagana, Kenya, during the period 26 November 1997 through 3 December 1998 (average of daily maximum and minimum observations). Maximum humidity near 100% was observed most nights except during periods when ponds were drained.

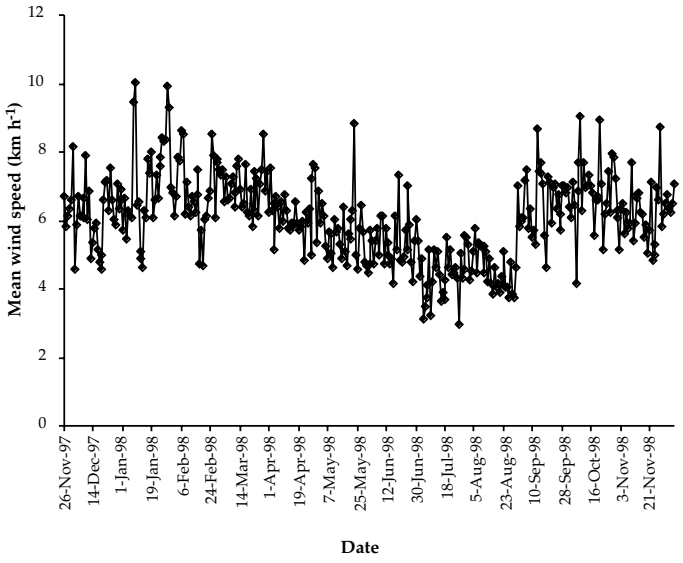

Figure 8. Daily mean wind speeds, in km h^{-1}, for the period 26 November 1997 through 3 December 1998 at Sagana Fish Farm, Sagana, Kenya.

conducted there. A fully functioning laboratory is an absolute necessity for carrying out the protocols established by the CRSP Technical Committee. With these physical improvements in place and the provision of a suitable vehicle for on-site operations and extension efforts and other farm operation tools, Sagana Fish Farm now has the physical capacity to conduct high-quality research; this in turn will contribute to the development of more efficient management strategies for use by fish farmers in the surrounding provinces, in the rest of Kenya, and in the region. Fish farmers will ultimately realize more efficient production in their ponds, and consumers will benefit from the resulting increases in the availability of food fish. Sagana Fish Farm also has the potential to become a center for practical training in the subjects of sex-reversal, pond construction, and laboratory techniques and could in this capacity serve not only Kenya but also other countries in the region.

LITERATURE CITED

Boyd, C.E., J. Queiroz, and C.W. Wood, 1999. Pond soil characteristics and dynamics of soil organic matter and nutrients. In: K. McElwee, D. Burke, M. Niles, and H. Egna (Editors), Sixteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 1–7.

Lutgens, F.K. and E.J. Tarbuck, 1992. The Atmosphere: An Introduction to Meteorology, Fifth Edition. Prentice Hall, Englewood Cliffs, New Jersey, 430 pp.

Vanlerberghe, K., personal communication, 1996.

Veverica, K., J. Bowman, and T. Popma, 2000. Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds. In: K. McElwee, D. Burke, M. Niles, X. Cummings, and H. Egna (Editors), Seventeenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 33–41.

Cite as: [Author(s), 2000. Title.] In: K. McElwee, D. Burke, M. Niles, X. Cummings, and H. Egna (Editors), Seventeenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, [pp. ___.]