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Chapter 31
Ecological management of a large coral reef eco-display at Burgers' Zoo, Arnhem, The Netherlands

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ABSTRACT

At Burgers' Zoo a large live coral reef eco-display has been constructed and is developing. Within this aquarium a living Indo-Pacific coral reef is growing that should resemble a natural coral reef. This display follows the Zoo's concept of eco-displays, where the visitor is submerged in a large display of a living biotope. This paper describes the build-up of this aquarium and the biological and chemical development over the last seven years. The management of this tank is based upon ecology, where nature itself is used to develop a healthy environment. The development of the biotope is a great educational tool to show the complexity of a coral reef. Only a small amount of external filtration is used to keep the water quality within limits. Most of the filtration capacity is developed within the substrate or by the developing food chains within the aquarium. Collection building is used to regulate the development within the reef. Biological control is used to try to keep the development within limits. Only 40% of the water is renewed every year, so understanding and monitoring chemistry is of utmost importance to manage this display. Within the paper the development of nutrients, calcium and magnesium is discussed.

INTRODUCTION

In 1988 Burgers' Zoo introduced the ecodisplay as a new exhibit-concept within the zoo characterized by large scale, highly naturalistic presentations, ecological connections, high biological diversity and biotope-immersion for the visitor (Janse and Wensing, 2000). After realization of a 15,000 m^2 tropical rainforest, a 7,500 m^2 representation of the Sonoran Desert and a mangrove exhibit, the latest project comprised an interpretation of the Indo-Pacific oceans showing several marine ecosystems, called 'Burgers' Ocean' (opened April 2000).
Within the aquarium one tank (volume 750,000 L) contains a live coral reef that grows within this philosophy. This aquarium harbors a carefully selected collection of animal species that fulfill several ecological tasks and demonstrates the biodiversity and typical characteristics of that system. Full development of the reef-ecosystem will take many years and species will be introduced in successive stages, dependant on the carrying capacity and environmental quality. This paper describes the first seven years of the development of the aquarium.

Technical setup

The decoration of the aquarium creates a base for the corals to grow on and show a close to naturalistic scene for the public. Five acrylic windows are placed in a way that the rockwork can be seen from different angles without seeing another window or any of the equipment or techniques used within the tank. Loose rocks were used as the outer layer of the decoration. Gunnite was used to build the rough alignment of the decoration. Plastic netting was fixed within the wet concrete and in between large amounts of plastic plugs (two types: EJOT Quickpin BN 6 x 50 with 6 mm hole and black plug with Ty-rap groove from Thomas & Best Ty-rap® Tie mounting base for masonry (TC5358) 6 mm diameter hole; use with ty-rap 5 mm wide max) were used to fix fibreglass reinforced rods (6 and 10 mm). The rocks were attached to these fixtures.

When the tank was empty 90 % (90 ton) of the concrete was covered with 'moon rock' (porous limestone rock) originating from South Africa. The tank was flushed two times with freshwater before filling it up with artificial seawater. When the tank was filled with seawater the open areas were filled with 'live rock' (total 10 ton) from Bali and Jakarta, Indonesia. After 2 years one major disaster happened within the aquarium, when all Nylon ty-raps used to attach the rocks started to break. Due to the artificial seawater the softeners within the cable ties leached out, making them brittle and easy to break. Different types of Nylon ty-raps of different brands had been used (3.6, 7.5 and 10.0 mm width), both black ('weatherable') and white (standard). All ty-raps had to be replaced. It was decided to us a special type ty-raps (PAN-TY Tefzel Fluoropolymer) together with a special type of Twaron rope (Teijin Twaron, www1). These materials were used together to reduce the risk of failure and subsequent damage to the reef. It took divers 1.5 years to replace all ty-raps.

Water movement

The water movement in the aquarium is created in three different ways: continuous, counter-current and surface flow. Four pumps with a total flow of 400 $m^3.h^{-1}$ create a constant flow in the aquarium. Via four large jets, situated parallel in the same direction. This laminar current ensures a homogenous water quality. Seven other pumps, with a total flow of 600 $m^3.h^{-1}$, each have one or two automatic valves placed in the pressure line. The suction of all pumps is placed behind a 0.5 mm mesh screen, to prevent life from entering the pumps. The outlets in the aquarium are placed opposite each other. Via automatic valves the direction of the water switches every three to ten minutes. All outlets are enlarged with eductors (Emperor Aquatics, www2), which increase the flow by approximately 20 % via venturi. This makes the total flow of the counter-current pumps around 700 $m^3.h^{-1}$. The effect of the counter-current pumps on the flow is astonishing. Beside the direct effect of the changing currents via the outlets these same changing currents have an effect on the laminar continuous flows. Fot the benefit of the corals, the direction and the quantity of the flow varies considerably throughout the aquarium.

A special device was used to create a surface surge: the oloid (www3). The oloid is a three-dimensional propeller, which is placed directly in the water just below the surface. This ensures a good surface movement and also large amounts of water are pulled underneath this device. The exact surge is unknown, but it moves approximately 200 $m^3.h^{-1}$. The total water movement within the tank was around 1,300 $m^3.h^{-1}$ or once every 38 minutes the aquarium. In 2005, the oloid was taken from the system due to technical problems. To decrease the energy consumption of the aquarium five external pumps (using a total of 25 kW) and the oloid were replaced by four submersible mixers. These mixers (WILO/EMU TR 28) each produce a surge of 500 $m^3.h^{-1}$ and use 1.3 kW. This change increased the total flow within the aquarium to approximately 3,300 $m^3.h^{-1}$ and decreased the total electricity pump consumption from 72 kW towards 50 kW.

Light

Natural daylight falls indirectly in the aquarium. During part of the summer, a maximum of two hours per day direct sunlight hits about 10 % of the water surface. Artificial light helps to create a surface PAR of 600-800 $\mu E.m^{-2}.s^{-1}$. Thirty-six lamps of 2 kW lamps (Philips MHN-TD 5600 K) create an even light level over the tank. In the last few years six 2 kW lights were replaced by 400 W (Sill 400 W spot with Aqualine 13,000 K; n=18) spotlights. This way less electricity is used and more light is brought to the corals. With a total surface of 220 m^2 this equals 344 $W.m^{-2.}$ All lights are switched on for 10 hours per day, with dusk and dawn occurring over one hour. Artificial moonlight is placed high above the water surface, which follows the natural moon cycle. The moon consists of ten bulbs (Philips PL), with no lamp burning at 'new moon'. A gradual increase (10, 15 or 20 W) in two-day steps leads to a maximum of 120 W at 'full moon'. All lights are replaced once a year over a one-month period. New lights are installed higher above the tank, and lowered within two weeks to create a gradual change in light intensity on the corals.

Water purification

The management of this coral tank is on an ecological basis, thus this mesocosm has limited external filtration. External filtration consists of two protein skimmers (see Appendix I) with a total flow of 60 $m^3.h^{-1}$ and total flow of 40 $m^3.h^{-1}$. The total external filtration flow is 85 $m^3.h^{-1}$ which equals a residence time of 8.5 hours. To prevent the water becoming green/ yellow and to break the long chain molecules ozone (0.05 mg $O_3.L^{-1}.h^{-1}$) is used within the protein skimmers.

Biological purification occurs within the aquarium in different living sand bottoms (total surface of 140 m^2), also within 'live rock', and through consumption by animals and algae.

In these area, different food chains and food webs are used to keep the water quality within limits. Organic matter, such as excessive food, excreted products or dead organisms is mineralised to dissolved organic carbon (DOC) and used partly by heterotrophic denitrifying bacteria or as food for other bacteria or organism (like corals). Denitrification in the rock and sand bottom will keep nitrate levels below 0.05 mg NO_3^--N.L^{-1}.

To clarify the philosophy behind this type of management, consider the example of a simple food chain: Bacteria are being fed organic matter; zooplankton feed on the bacteria and fish eat the zooplankton. This food chain needs a constant influx of organic matter to feed the bacteria. This is accomplished by manually feeding the fish and other organisms. Excess fish food and excretion products from these organisms provide food for the bacteria. When too little is fed the bacterial biomass drops, followed by a decrease of living zooplankton in the tank. Continuous efforts are necessary to maintain a biological balance. The successful recruitment of fish hatched within the aquarium that are not manually fed, such as *Pterapogon kauderni* and *Acanthochromis polyacanthus,* has demonstrated the existence of a viable zooplankton community within the tank.

One of the pillars of ecological management is the feeding of the system. During the first years, no manual feeding was conducted. When the nitrate level dropped below 0.1 mg NO_3^--N.L^{-1} feeding was started. From then on, more planktivorous fishes could be introduced within the mesocosm (Figure 1).

Animal collection

As previously stated, the management of the eco-display is based upon ecology. Therefore, every animal and plant should have a function within the biotope. Balancing the developing coral reef is a big challenge. Some pioneer species will overgrow and dominate areas of the tank, especially in the first few years. For example the hydroid polyp, *Myrionema amboinensis* covered nearly 50 % of the rocks at some time. Due to their strong nematocysts, they created a lot of problems with competition for space. Sea urchins such as *Diadema setosum* and *Echinothrix calamaris* seem to help to clean some areas and at times, the hydroids were manually removed around the corals. This hydroid is mostly found in areas with the highest light conditions and low current (< 0.1 m.s^{-1}). Increasing the water movement and increasing the competition on the substrate did have a negative effect on the hydroid population. Due to an increase in calcium and magnesium concentration an increase of calcareous algae was seen, which also increased competition for space and thus decreased macro algae and hydroid populations.

The foraminiferan, *Heterostegina depressa* used a lot of space, but never became a problem for the corals. *H. depressa* was living on sand, directly on rocks, or in between the thali of red algae (*Gelidium* sp. (Rhodophyta, Gelidiales)). The introduction of *Macropharyngodon* wrasses

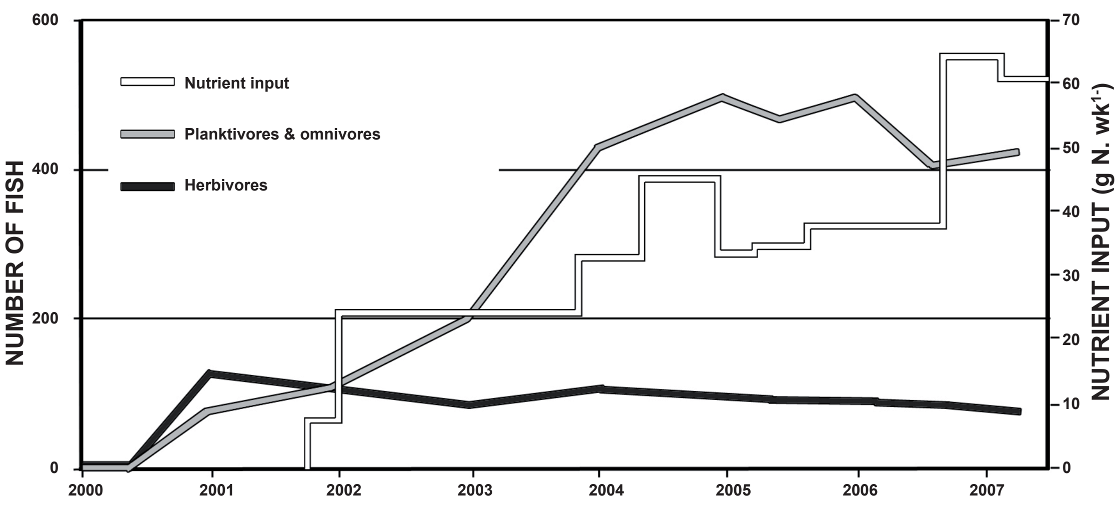

Figure 1: Development of the number of herbivorous and planktivorous fish and the nutrient input (as food)

did help control them. Decreasing the organic carbon level may also have directly caused a decrease in the foraminiferan population, or indirectly due to the decrease in the red algae on which *H. depressa* was living in high numbers.

Other pest species included *Aiptasia* sp., which increased drastically the first year and was controlled by four *Chelmon rostratus* and six *Chaetodon kleini* butterflyfishes. However the *C. kleini* started to eat corals when the *Aiptasia* sp. were gone, and thus the fish had to be removed. The *C. rostratus* kept the *Aiptasia* within limits. A limited number of *Anemonia* cf. *majano* were found and manually removed. In 2002 a large population of *Planaria* sp. developed on the rocks and corals. The introduction of wrasses (*Pseudocheilinus hexataenia*) and dragonettes (*Synchiropus ocellatus*, *S. splendidus* and *S. pictoratus)* controlled them within a few months. Killer sponge colonies, *Colliospongia auris*, were growing to 10 cm diameter and were removed manually together with the substrate. The moorish idol, *Zanclus cornutus,* was introduced to help to keep sponge growth within limits. Many herbivorous fishes like *Acanthurus* spp. (8 species), *Ctenochaetus strigosus*, *Paracanthurus hepatus* and *Siganus* spp. (2 species) and other animals like hermit crabs (e.g. *Calcinus* sp.), sea urchins (e.g. *Diadema* sp., *Echinothrix calamaris*) and snails (e.g. *Turbo* sp.) were introduced to keep the (macro) algae population within limits. *Bryopsis* sp. was the only species that returned every year during spring and summer in the shallow areas.
Detritus was removed by many fish species, especially *Ctenochaetus strigosus*, many worms (including 1 m long polychaete worms (*Eunice* sp.; Eunicida)), some holothurians (*Holothuria atra*), sea stars (*Astropecten* sp.) and a healthy population of amphipods. Introduction of *Valenciennea puellaris*, *Amblygobius phalaena* and *Malacanthus latovittatus* helped to stir the top layer of the coral sand. The last species also kept the worm population in the substrate within limits. Nonetheless, cyanobacteria were abundant on the coral sand, possibly caused by the available sink of phosphates within the substrate. More activity on the substrate will be necessary. In the near future more bottom dwelling fishes like gobies, goatfishes (*Parapuneus* spp.), and a small sting ray, *Dasyatis kuhlii,* will be introduced. Appendix II gives an overview of the current fish collection within the display.

Corals are introduced manually. The coral population is counted once a year. An excel file is kept and the total coral administration is kept in Animal Record Keeping System (ARKS). The different coral species were captive bred in other public and private aquaria, appeared on live rocks or were obtained from confiscations of illegal imports at Amsterdam International Airport (Figure 2). Two coral fragmentation facilities (volume of 4,000 and 6,000 L) at Burgers' Ocean increase the number of colonies per species available for use in the coral tank and for exchange with other institutions.
Four species of coral are reproducing sexually: *Echinopora* sp. (since 2004), *Favites* sp. (since 2005), *Favia* sp. (only 2005) and *Seriatopora caliendrum* (since 2006). However the last

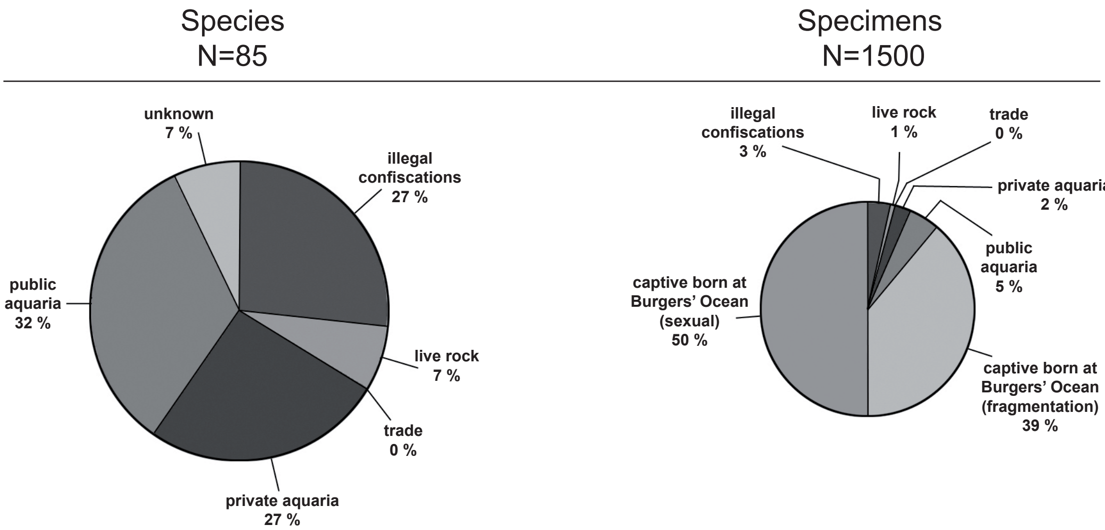

Figure 2: Overview of the origin of both species and specimens of Scleractinia collection with the coral reef display at Burgers' Ocean

species may also reproduce by budding. The new *S. caliendrum* were found everywhere within the tank from 0 to 2 m depth, far away from mother colonies.

Water management

Nutrients are measured once a month using HACH spectrophotometer (nitrate with HACH method 8192; phosphate method 8048 and nitrite method 8507). Macro-elements and alkalinity are measured once to two times per month using HACH titration (calcium method 8204; magnesium method 8213 and alkalinity method 8203).

Figure 3 shows the changes of phosphate and nitrate over time. After the first peek nitrite stabilized at 0.003 mg NO_2^--N.L^{-1} and nitrate at 0.04 mg NO_3^--N.L^{-1} . Phosphates were as low as 0.015 mg PO_4^{3-}.L^{-1}. In the first six months of the development of the aquarium the excessive algae community took out most of the nitrates.

Algae biomass decreased over time due to manual removal, consumption by introduced herbivores and overall nutrient depletion within the tank. As a result, denitrification and

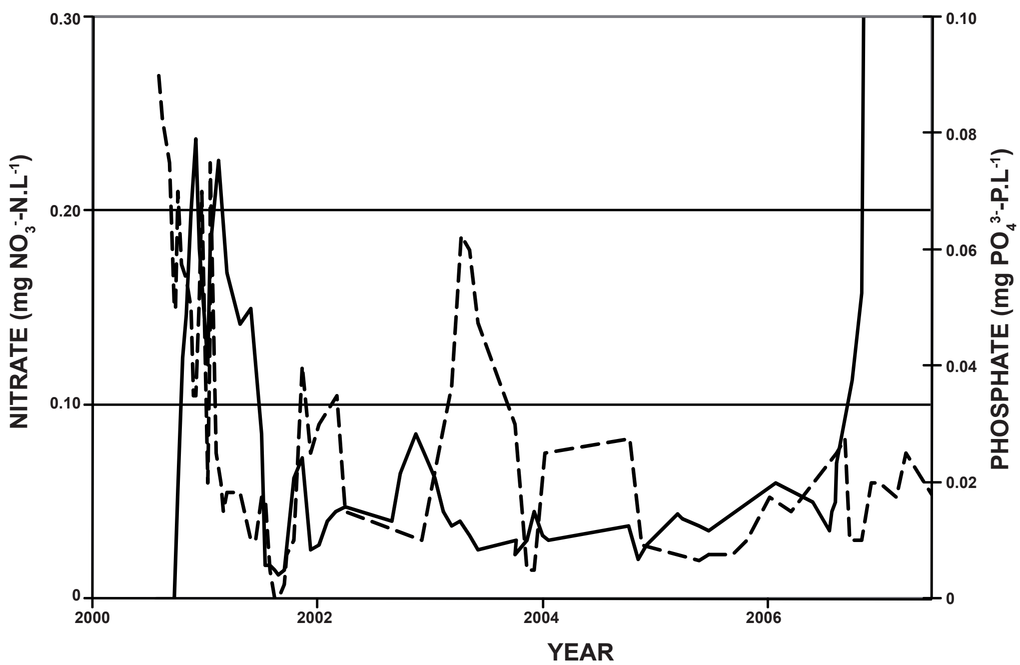

Figure 3: Nitrate (—) and phosphate(- -) changes over time

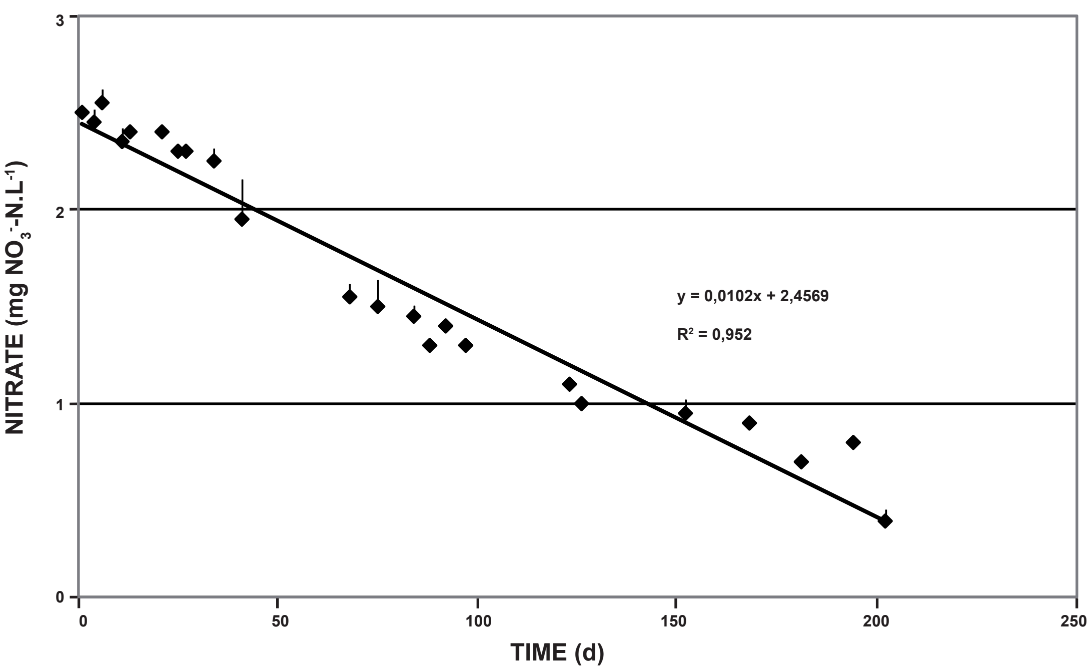

Figure 4: Decrease in nitrate concentration from January 4th 2007 (t=0)

consumption by zooxanthellae became more important. To prevent nutrient levels from getting too low and the animals from starving, food was given from 2001 onwards. A mistake was made in January 2007 when sodium nitrate was added instead of sodium carbonate. This increased the nitrate towards 2.4 mg NO_3^--N.L^{-1}. No adverse affect was seen on the coral population, and the nitrate level decreased again in the next six months (Figure 4). The depletion of nitrate was linear at an average nitrate removal of 0.0102 mg NO_3^--N.L^{-1}.d^{-1} (=7.65 g NO_3^--N.d^{-1}). In the same period 5.4 g N.d^{-1} was added as food to the aquarium. During this period, the water changes were similar to those in earlier periods. In the first five years only 40 % of the water was changed per year (as daily water changes), but from 2006 this has been increased to 100 % per year. Artificial seawater was made from Tropic Marin Zoo mix salt (excluding bromide) at a salinity of 34 ppt.

Calcium is the most important macro element due to calcification of Scleractinia and calcareous algae. The calcium concentration within the tank is shown in figure 5. In the first one and a half years the calcium level increased from 400 to 480 mg.L^{-1}. This was likely a result of calcium leaching from the concrete within the tank. During this period pH was stable at 8.0-8.2. Starting in 2002 the calcium level was diminishing due to the increase of calcium consumption by organisms, calcium phosphate precipitation from increasing food input and a possible decrease of calcium leaching from the concrete. The production of calcium was expected to increase within the live sand due to dissolution of the coral sand in an acidic environment. Measurements of the deeper parts of the sand layer showed only a slight decrease of the pH (0.1 to 0.3 lower than in the aquarium) and thus had little effect on the calcium production. Even the increase in nutrient input had no significant affect on the activity within the live sand, and the oxygen concentration remained between 60 and 92 % within the bottom showing that little bacterial activity was present at the time. When calcium diminished to 370 mg.L^{-1}, alkalinity to 1.6 mEq.L^{-1} and pH to 7.8 a combination of sodium carbonate and sodium bicarbonate (1:6 w:w, total 40 kg) was added to the system in August 2003 over a period of ten weeks. Alkalinity went up to 2.1 mEq.L^{-1}, pH (at 7.9) and calcium stayed constant. In March 2004 a calcium reactor (Schuran type CR 500, volume 160 L at 150-200 L.h-1 and pH of 6.3 and 6.5) was introduced. pH within the aquarium stabilised at 7.9, alkalinity at 2.5 mEq.L^{-1} and calcium slowly rose to 400 mg.L^{-1}. The growth of many Scleractinia improved significantly when calcium level increased to 390 or higher. Beginning in December 2005, ALSO kalkwasser (160 L.d^{-1}) was added to the system, to keep calcium concentration between 400 and 420 mg.L^{-1}.

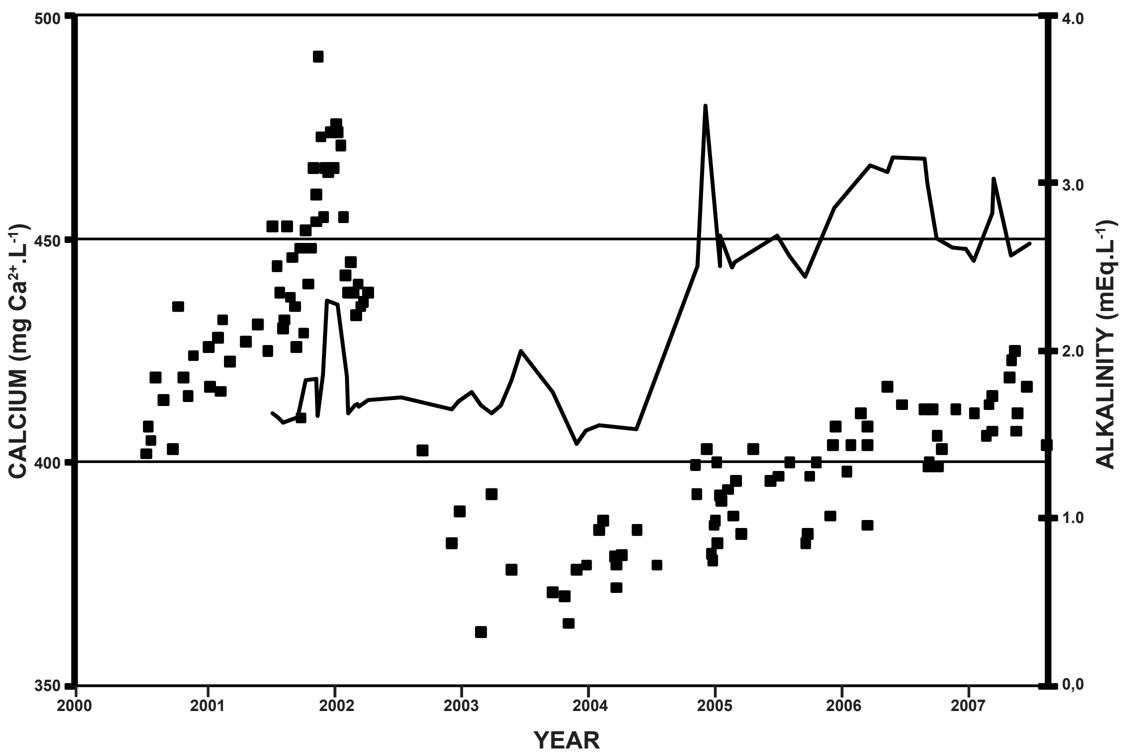

Figure 5: Changes in calcium concentration (■) and alkalinity (▬) over time

The magnesium level was constant at a range of 1050 and 1200 $mg.l^{-1}$ until 2005. Within the calcium reactor, 10% of the volume consisted of shells (mixture of tropical snails and bivalves made from high magnesium calcite) was introduced to increase the magnesium level, though this had little effect. In 2005 it was decided to add magnesium to the system as $MgCl_2.6H_2O$ and $MgSO_4.7H_2O$ (in a weight ratio of 12.3:1) to the set point of 1300 $mg.L^{-1}$ in 4 months time. These additions are still in progress.

Every four to six months the major trace elements are measured via ICP Mass Spectrophotometer. Trace elements are added to the system via water changes, feeding and dissolving of coral sand in the calcium reactor and living sand bottom. Strontium increased from 7 to 9 $mg.L^{-1}$ in the first year. After three years the strontium level stabilized around 9 $mg.L^{-1}$. After the introduction of the calcium reactor in 2004 the strontium level increased to 10 $mg.L^{-1}$. However increasing biomineralization of Scleractinia and calcareous algae decreased the concentration again. This is why since 2005 strontium has been added to the system. Beside strontium, iodine, iron and barium have also been added to the system since 2005 (for details see Appendix I).

CONCLUDING REMARKS

Ecological management has a lot of potential in such large coral reef aquaria. The large volume has the advantage of slowing processes or changes. However when the chemistry changes it is more difficult to adjust it properly. Time is an important factor when running a tank like this. The development is a slow process, but thus also a great educational tool for the public. Coral development is slow when it's decided to work as much as possible with captive propagated corals.

ACKNOWLEDGEMENTS

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INTERNET RESOURCES

www1. www.teijinaramid.com
www2. www.emperoraquatics.com
www3. www.oloid.ch

APPENDIX I: Aquarium Passport, Technical and chemical details

Tank name	Coral reef
Location	Burgers' Ocean at Burgers' Zoo (Arnhem, the Netherlands)
Opening date	June 2000
PHYSICAL DESCRIPTION	
Volume	750,000 L
Surface area	220 m^2 ~ 15 x 15 m, very complex shape
Depth	Max. 6 m
LIGHT CONDITIONS	
Natural	Some indirect natural light through transparent roof and a little bit of direct sunlight in summer
Artificial	- 33 x 2,000 W Phillips MHN-TD 5,600 K - 21 x 400 W Aqualine 13,000 K - Total: 74,400 W or 340 $W.m^{-2}$
Moonlight	OSRAM CL E27/ES bulbs 0, 15, 25, 40, 60, 75, 85, 120 W increasing towards full moon and reverse for new moon
FILTRATION (external)	
Prefilter	Sacks 0.5 mm mesh for all water being filtered and circulated till 2006. Since 2007 3 mm meshed PVC
Model	Schuran Aquaflotor AQ 800 (x 1) and AQ 500 (x 1)
Flow	45 $m^3.h^{-1}$ and 20 $m^3.h^{-1}$ 65 $m^3.h^{-1}$ in total
Ozone injection	0.005 mg $O_3.l^{-1}.h^{-1}$ at each passage through protein skimmers
Sand filters	2 Triton 100 HR sand filters (V=400 L; Q=20 $m^3.h^{-1}$ per filter; medium sand)
Total external filtration	85 $m^3.h^{-1}$ ~ 8.5 h residence time
FILTRATION (internal)	
Live-rocks	10 tons 'live rock' and 80 tons 'dead rock' (~ 12 % of tank volume)
Sand	- 21 tons of different grade coral sand - Jaubert filter divided in several sections physically separated - Double layer above plenum: ~5 cm of sand covered by PVC plate with holes throughout, covered by ~10 cm of sand again Total living sand area = 140 m^2
WATER MOVEMENT / CIRCULATION	
External pumps	2 pumps, total 200 $m^3.h^{-1}$ in one direction 6 pumps total with eductors changing directions every 3-10 minutes, total 300 $m^3.h^{-1}$
Submerged pumps	4 mixers (EMU model TR28.145-4/11) creating currents over 20 m range, estimated to be running at 500 $m^3.h^{-1}$ per mixer
Wave machine	None
Total flow	~3,300 $m^3.h^{-1}$ of which 95 % is unfiltered
Filtration flow	85 $m^3.h^{-1}$
Aeration	Air stone (0.5 m length x 10 cm diameter) at night for 10 hrs
WATER CHANGES (with "new" salt water)	
Type of system	Totally closed

APPENDIX I (continued): Aquarium Passport, Technical and chemical details

Characteristics of "new" saltwater	Calcium: 370 mg $Ca^{2+}.L^{-1}$		
	Magnesium: 1220 mg $Mg^{2+}.L^{-1}$		
	Alkalinity : 2.7 $mEq.L^{-1}$		
Rate of water replacement	40% per year with artificial salt-water (Tropic Marin Zoomix excluding bromide), from 2006 100% per year (as daily water changes)		
FEEDING REGIME			
Dead food	~0.73 kg per day Frozen *Artemia*, red plankton, krill, mussel, shrimp, spirulina flake, pea, and salad		
Live food	None		
WATER QUALITY (current value (range))			
Salinity	~34 ppt (online WTW LF 296 with WTW TetraCon® 700 probe; topped up with reversed osmoses or new salt water)		
Temperature	Very stable at ~26°C, up to 27 °C in summer Controlled online WTW pH 296, heated or cooled depending on the needs		
pH	7.85 (7.8-8.1) (online WTW pH 296 with WTW Sensolyt® SEA probe)		
Redox (mV)	280-320 mV (online WTW pH 296 with WTW Sensolyt® PtA probe)		
Dissolved Oxygen	~100% (online WTW Oxi 296 with WTW TriOxmatic® 690 probe)		
Alkalinity	2.7 (1.4 – 3.2) $mEq.L^{-1}$		
Nutrients	Nitrate (mg NO_3^--N.L^{-1}):	0.38	(0.05-2.40)
	Nitrite (mg NO_2^--N.L^{-1}):	0.002	(0.002-0.005)
	Phosphate (mg PO_4^{3-}-P.L^{-1}):	0.003	(0.001-0.005)
Macro elements	Calcium (mg $Ca^{2+}.L^{-1}$):	418	(364 - 450)
	Magnesium (mg $Mg^{2+}.L^{-1}$):	1376	(1060 -1410)
	Sulphate (mg SO_4^{2-}-S.L^{-1}):	811	(785 - 839)
Trace elements	Strontium (mg$Sr^{2+}.L^{-1}$):	9.6	(6.9-10.2)
	Potassium (mg K.L^{-1}):	422	(400-430)
	Molybdenum (µg Mo.L^{-1}):	22	(16-29)
	Barium (µg Ba.L^{-1}):	50	(dropped from 72 to 15, since addition around 50)
CHEMICAL ADDITIONS			
Calcium	Calcium reactor (installed March 2003): Coral sand (same sand as inside tanks) Consumption: 250-400 kg coral sand per year		
Calcium hydroxide	Calcium hydroxide (starting November 2005): - mixed for 1 hour, settled for 8 hrs, dripping into tank over 8 hours in strong current - 160 $L.d^{-1}$		
Calcium chloride	- For emergency addition only if Ca^{2+} < 390 mg Ca.L^{-1} since 2005 - Add 25 kg $CaCl_2.2H_2O$ in 5 days - Dissolve and add via the daily demi water addition system		
Bicarbonate	Sodium bicarbonate: - added at same period (but different days) as calcium chloride or magnesium chloride is added, not for alkalinity control but for ion balance between chloride and sodium - Dissolve and add via the daily demi water addition system		
Magnesium	-added only when magnesium level under 1,200 mg.L^{-1} since 2006 -than 100 kg $MgCl_2.6H_2O$ and 8 kg $MgSO_4.7H_2O$ (in a weight ratio of 12.3:1) in 8 weeks time		

APPENDIX I (continued): Aquarium Passport, Technical and chemical details

Trace elements	Strontium:	80 ml.wk^{-1} of 500 g $SrCl_2.6H_2O.L^{-1}$ since August 2005
	Barium:	160 ml.wk^{-1} of 25 g $BaCl_2.2H_2O.L^{-1}$ since March 2006
	Iodine:	160 ml.wk^{-1} of 5 g $KI.L^{-1}$ since January 2006
Nutrients	Nitrate:	10 ml.wk^{-1} of 257 g $NaNO_3.L^{-1}$ since September 2007

APPENDIX II: Fish population (56 species and 531 animals) in coral reef tank at Burgers' Zoo, Arnhem (August 1st, 2007)

Genus	Species	#	Genus	Species	#
Acanthochromis	*polyacanthus*	84	*Dascyllus*	*aruanus*	2
Acanthurus	*achilles*	2	*Genicanthus*	*lamarck*	3
Acanthurus	*dussumieri*	3	*Genicanthus*	*melanospilos*	4
Acanthurus	*leucosternon*	13	*Halichoeres*	*leucoxanthus*	1
Acanthurus	*nigricans*	4	*Labroides*	*dimidiatus*	2
Acanthurus	*olivaceus*	5	*Macropharyngodon*	*bipartitus*	5
Acanthurus	*pyroferus*	8	*Macropharyngodon*	*negrosensis*	5
Acanthurus	*tennentii*	4	*Malacanthus*	*latovittatus*	1
Acanthurus	*triostegus*	2	*Naso*	*vlamingii*	5
Amblyeleotris	sp.	1	*Nemateleotris*	*magnifica*	2
Amblygobius	*phalaena*	5	*Oxycirrhites*	*typus*	2
Amblyglyphidodon	*aureus*	4	*Paracanthurus*	*hepatus*	12
Amphiprion	*clarkii*	1	*Pomacentrus*	*auriventris*	15
Amphiprion	*melanopus*	4	*Pomacentrus*	*moluccensis*	10
Amphiprion	*ocellaris*	2	*Pseudanthias*	*squamipinnis*	17
Apogon	*cookii*	1	*Pseudocheilinus*	*hexataenia*	3
Apogon	*leptacanthus*	30	*Pseudochromis*	*paccagnellae*	10
Centropyge	*eibli*	2	*Pseudochromis*	*splendens*	3
Chelmon	*rostratus*	2	*Pterapogon*	*kauderni*	7
Chromis	*margaritifer*	18	*Salarias*	*fasciatus*	1
Chromis	*viridis*	150	*Scarus*	*quoyi*	2
Chrysiptera	*cyanea*	6	*Siganus*	*guttatus*	2
Chrysiptera	*hemicyanea*	20	*Siganus*	*puellus*	2
Chrysiptera	*parasema*	2	*Siganus*	*vulpinus*	11
Chrysiptera	*springeri*	5	*Sphaeramia*	*orbicularis*	1
Chrysiptera	*talboti*	1	*Synchiropus*	*ocellatus*	10
Cirrhilabrus	*lubbocki*	2	*Thalassoma*	*hardwicke*	1
Cryptocentrus	sp.	1	*Zanclus*	*cornutus*	1
Ctenochaetus	*strigosus*	6	*Zebrasoma*	*scopas*	3