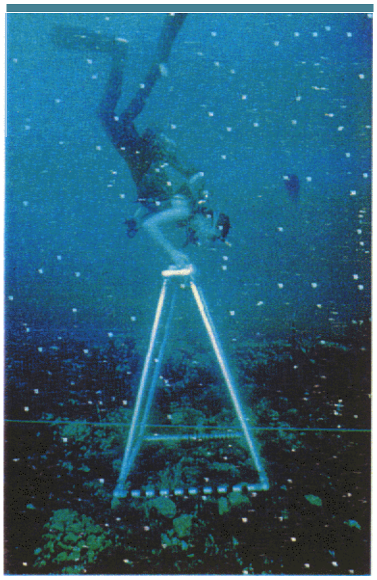
Appendix A: Underwater Photography

Of the many methods available for photographic sampling, six devices are described in this section in approximate order of increasing complexity. Although these devices vary in sophistication and cost, the goal is always to make sure that each photograph is taken of the exact same area, at the exact same distance and angle. These methods will continue to evolve as experience and new technology lead to better techniques. For more general information and suggestions about underwater photography, see III-29.

Method A: Quadrapod for Large Photo-quadrats

In quadrapod methods, an underwater camera is mounted in the center of an aluminum or PVC frame with the lens facing the substrate. Four legs made from l-inch PVC pipe that connect this frame to the corners of a larger rectangle (the photo-quadrat), so that the apparatus looks like a 3-dimensional trapezoid. To secure a Nikonos to a 7/8-inch thick PVC mounting plate, use a ¼-inch bolt that threads into the tripod mount of the camera. Using Ikelite "quick handles" and 18-inch supports, you can also attach two strobes to the back of the mounting plate, or a single SB103 strobe to the top of the frame.



Quadrapod for Large Photo-quadrats

The exact dimensions of the quadrapod will depend on the size of the area you wish to photograph and your lens size, but you can use this method to photograph large areas without expensive equipment. This approach can also be used to take photographs along a transect line stretched between two permanent reference markers

For example, to cover an area of approximately 5.5 x 80 cm with moderate or no relief, you could use a 28-mm Nikonos lens with a quadrapod that holds the camera 95-cm above the reef surface. Or, if the focal plane of the film is located 1.63 m above the quadrapod base. your photograph will cover a 1 x 0.75-m area.

Although automatic "through-the-lens" exposure will work, using the camera on a manual setting will give you a more consistent color balance between frames, e.g., f/8 or f/11 at 1/60th of a second exposure with IS0 64 or 110 slide or print film.

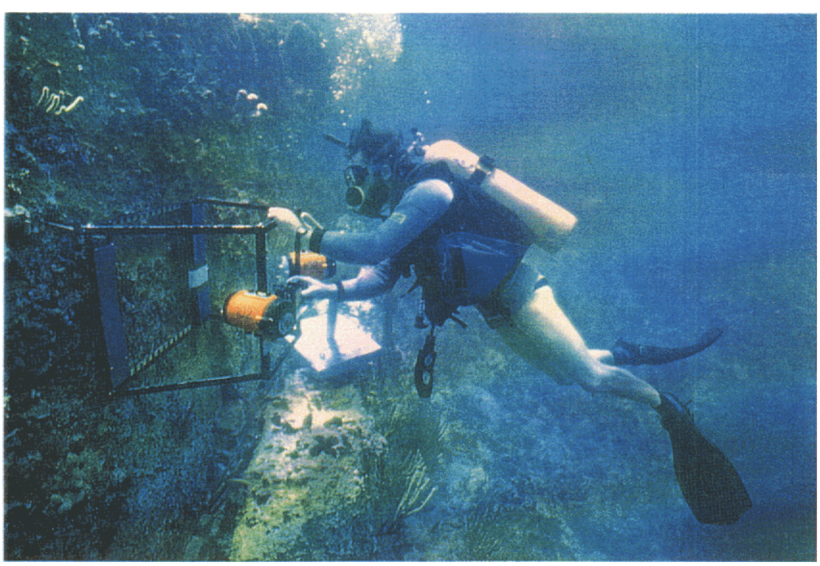
At study sites 10 to 30 feet deep in the U.S. Virgin Islands, good results have been obtained with Kodachrome 64 film, a shutter speed of M90, aperture 5.6, focus 1.2 m, and manual settings. The minimum reliable resolution is for organisms with about 4 to 5 cm diameter, but the large scale of the photographs results in underestimating the corals growing in hollows and cracks not visible in the slides.

(Pete Edmunds, California State University, provided most of the information on this method.)

Method B: Quadrapod for Small Photo-quadrats in Low Relief Areas

This method is appropriate for reef surfaces with low relief, such as encrusting communities It allows the largest possible area to be photographed with the camera close to the subject, increasing the clarity and compactness of design.

Mark two diagonal corners of each permanent quadrat (0.25 m^2) by cementing two stainless steel rods into holes drilled in the substrate. The rods can serve as alignment points for the corners of a quadrapod that will support two strobes and a Nikonos camera with 15-mm lens



Quadrapod for Small Photo-quadrats

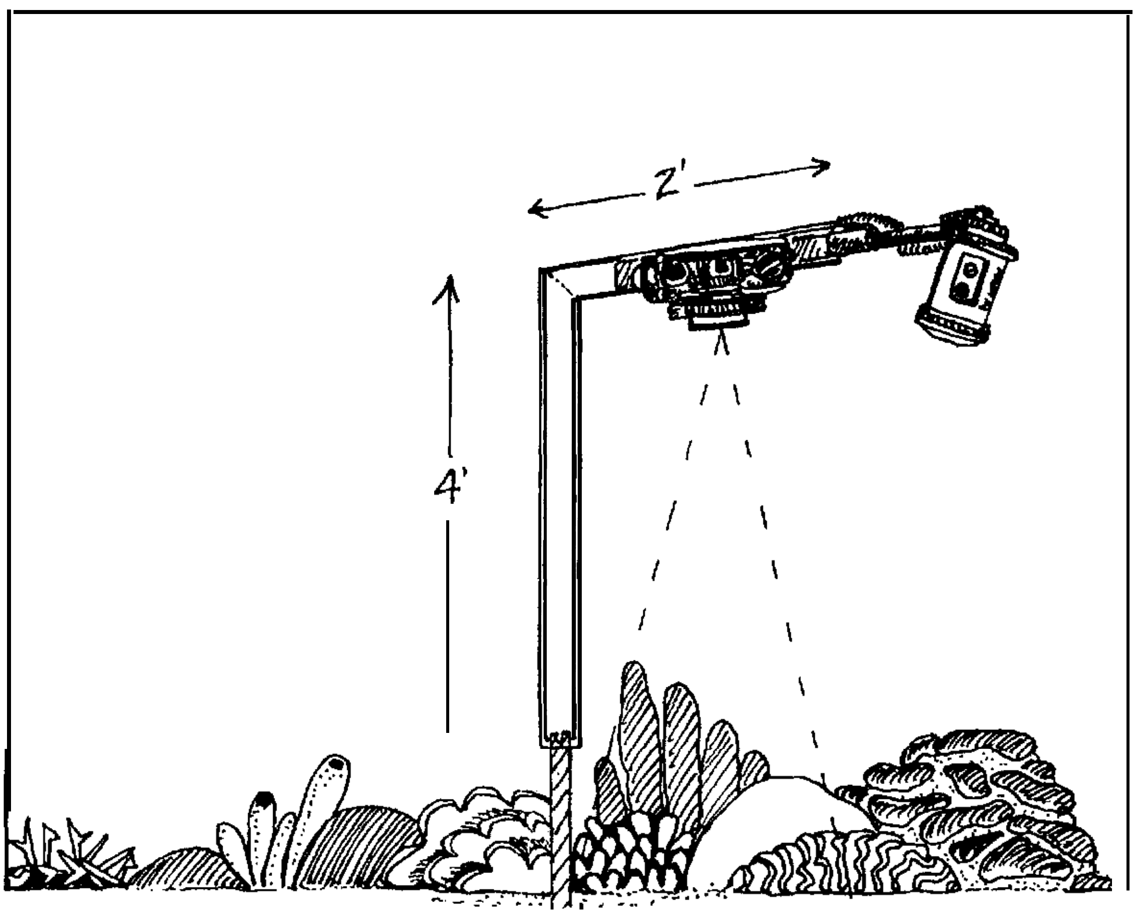
Reference

Coyer, J. and J. Witman (1990) *The Underwater Catalog: A Guide to Methods in Underwater Research*, Shoals Marine Laboratory and New York Sea Grant Program, Cornell University, Ithaca, New York

Method C: Monopod

In this method, the only structure that touches the reef substrate is the survey stake holding the photostand, or "monopod". Especially in areas where corals are large or abundant, these methods are less likely to cause damage than those which require supporting a camera on a bulky frame or quadrat. However, like quadrapods, monopods are better suited to areas without high relief.

The camera is attached to the monopod, an L-shaped apparatus that is fitted over a permanently installed survey stake. Although you can vary the dimensions of the photostand according to the size of your chosen photo-quadrat and the relief of the substrate you are photographing, the long side of the monopod is generally about 4 feet, and the short side about 2 feet. The higher the photostand, the greater the potential for parallax.



Monopod

Constructing a Monopod Photostand

1) Using square aluminum tubing with an inside diameter of 1 inch, weld a 2' piece to a 4' piece at a 90 degree angle.

2) Weld a mounting plate to the 2' piece.

3) Screw the camera onto the plate so that the lens faces the substrate.

4) Using a pneumatic drill and %-inch bit, drill a hole in the pavement or dead coral to a depth of about 1 foot.

5) With a sledgehammer, pound a piece of 1 inch square stainless tubing approximately 1' long (the reference "stake") into the hole.

6) To increase the stake's stability, use Pettit 2-part underwater patching compound to epoxy it into place.

Taking the photographs: Mount a Nikonos V underwater camera with a 28-mm lens and a single SB103 Nikonos strobe with diffuser on the photostand. Slip the photostand over the stake and rotate it to take photographs at each of the four possible locations. With a preset focal length of 1.3 m, the total coverage area of each photograph will be 0.7 m^2 (2.8 m^2 per stake).

(This photographic method was developed by Craig Tobias, Virginia Institute of Marine Sciences, and Walter Jaap, Florida Marine Research Institute.)

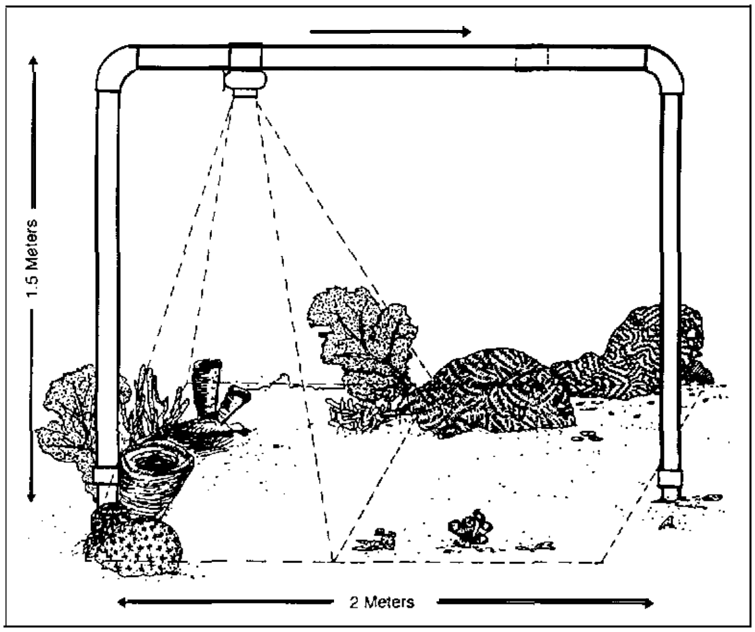
A monopod apparatus has been developed which uses a stereophotographic system to do three-dimensional analysis, but analyzing the data from such techniques and replicating exact camera position over time are difficult.

Reference

Done, T.J. (1981) "Photogrammetry in coral reef ecology: a technique for the study of change in coral communities," Proceedings of the 4th International Coral Reef Symposium, Manila, Philippines 2:315-320

Method D: Camera Mounting Frame

This apparatus for mounting a camera tits has two points of support on the substrate, so that you can move the camera along a horizontal bar and take a series of photos at designated positions which can be replicated in subsequent surveys.



Camera Mounting Frame

Constructing a Camera Mounting Frame

1) For a camera mounting frame to photograph two adjacent $1m^2$ quadrats, cement two 1%" PVC fittings 2 meters apart on the reef using a mixture of Portland cement and plaster of Paris.

2) Insert two PVC uprights supporting a 2-m **horizontal** bar with elbows into the PVC fittings. The length of the uprights is determined by the focal length of your camera lens: a 15-mm lens supported 1.5 m above the substrate will cover slightly more than $1m^2$; a 28-mm lens will need to be slightly higher to get the entire quadrat in the photo.

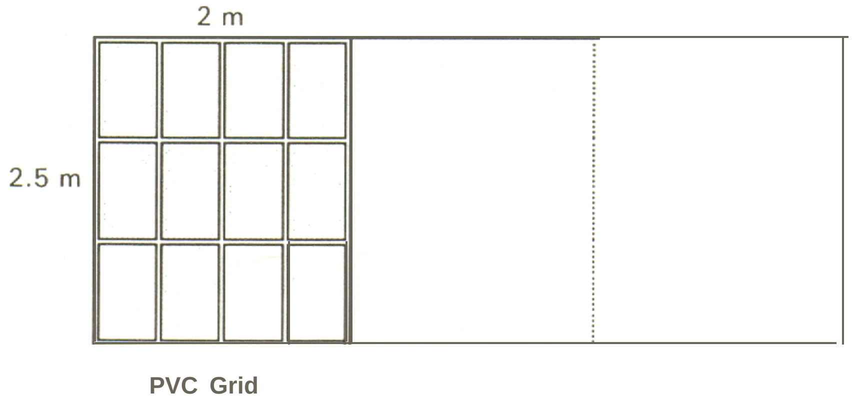
3) Using screws or etched lines, mark the horizontal bar at 0.5 and 1.5 m along its length to indicate where the camera is to be positioned for the two photos.

4) To permit easy positioning of a mylar tracing grid over the photographs, attach a taut line between the uprights just above the substrate with a bead at 0.5 and 1.5 m to indicate the center of each quadrat.

(This method was developed by Allan Smith, Caribbean Natural Resources Institute.)

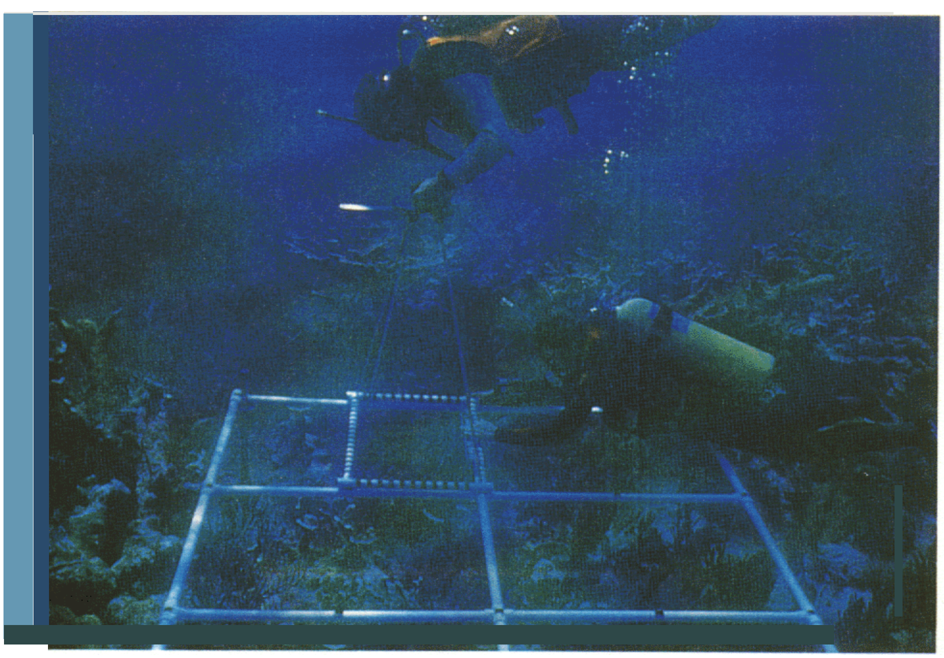
Method E: Photostation

This "photostation" is marked by 8 stainless steel stakes which frame a three-part quadrat as shown below. The stakes are inserted into holes drilled in the reef and cemented in place. One-inch PVC pipe is used to construct a grid measuring 2.25 m x 2 m with 12 rectangles, each measuring 0.75 m x 0.5 m.



Photostation Quadrats

The PVC grid is used as a guide for a camera attached to a quadrapod photoframer with a base of 0.75 m x 0.50 m. Place a Nikonos fitted with a 28-mm underwater lens 1 m above the grid to include the framed area in the photo. To cover the area marked off by the eight stakes (13.5 m^2), move the grid three times and take 36 photographs. Each photo should include a velcro-backed frame number and a small placard with date and place information.



Photostation Apparatus

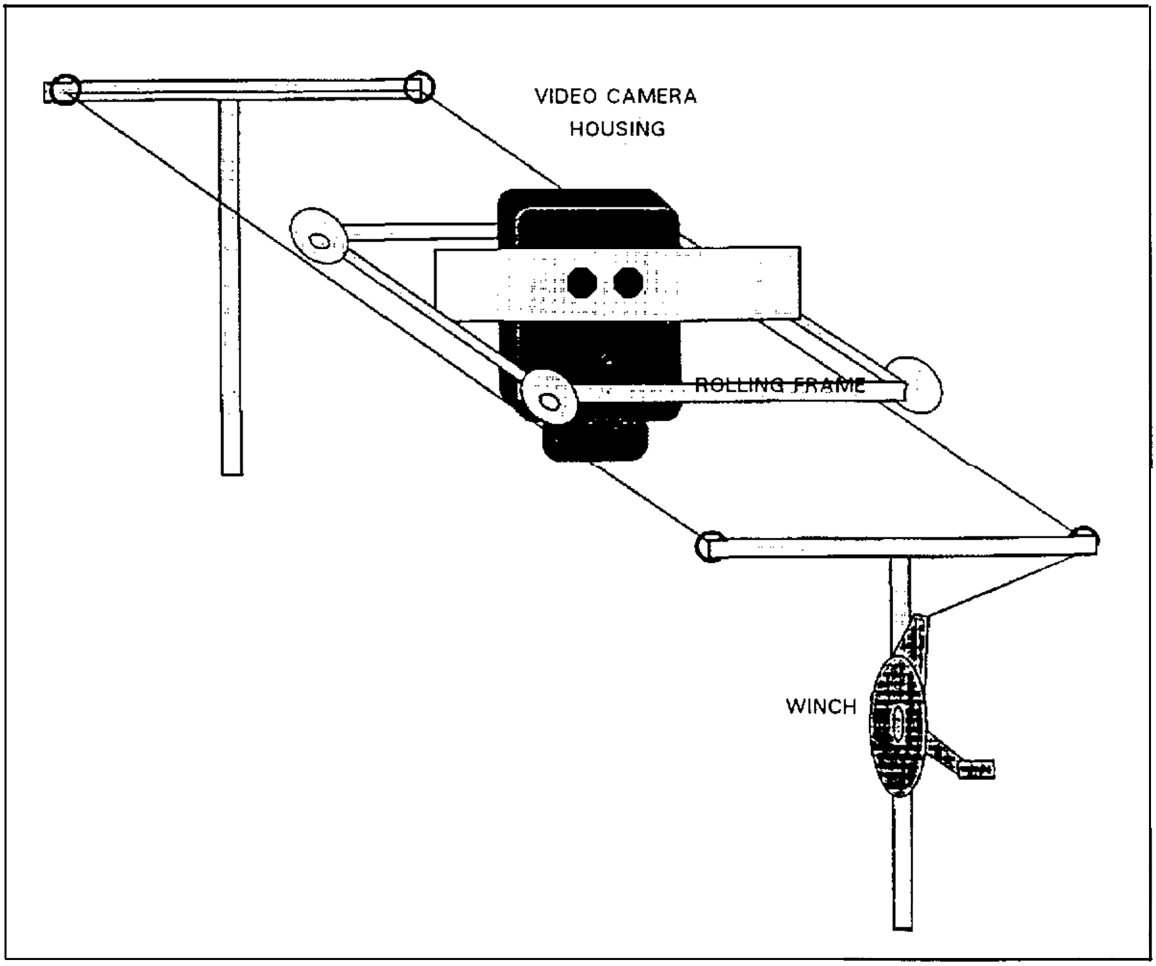
Considerations: This method has limited application. Because of the large size of the apparatus, it can only be used in certain locations, and because of the time required, it is difficult to get sufficient replicates. The PVC frame is not rigid, so the photoframer may move. Assembling a series of photographs to create a mosaic is problematic; the magnification changes from photograph to photograph because of parallax and the irregular surface.

Reference

Porter, J.P. (1990) Methods for the analysis of coral reef community structure. I. Photostation, A. Field methods and data acquisition. Report to National Park Service.

Videotaping

This apparatus can be used to videotape a reef using a Sony TR81 hi-band 8 camera in an Amphibico housing.



Videotaping Apparatus

- The housing is mounted on an aluminum "carriage" with four grooved, nylon wheels that roll on two cables deployed between two T-shaped aluminum poles that are slipped over square reference stakes. A stainless steel cable is deployed from a "down-rigger" fishing winch mounted vertically on one pole.

- After the clutch on the winch is released, a diver swims with the cable to the other pole, slips the cable through two eyebolts on the top of the T, returns the cable to the first pole, and snaps the stainless steel clip on the cable end to another eyebolt. Tension is taken up with the winch until the cable is taut, and the clutch is re-engaged.

- With the camera aimed vertically, the video carriage is suspended on the cables as the diver pushes it very slowly to the opposite pole and back, providing a video record of the reef area between the stakes. A tape measure in the video field provides a size reference.

Because there is some bowing in the middle of the cable and the sea floor is irregular, the camera cannot be maintained at a fixed distance from the bottom. Once on site, the time required to deploy and recover the equipment is about 10 minutes.

Reference

Jaap, W.C., Wheaton, J.L., Donnelly, K.B. (1990) "Materials and methods to establish multipurpose. sustained, ecological research stations on coral reefs at Dry Tortugas," Proceedings of the American Academy of Underwater Sciences, 10th Annual Scientific Diving Symposium, pp. 193-211.

Appendix B: STATISTICAL ANALYSIS

While a detailed explanation of statistics is beyond the scope of this manual, some generalizations can be made about statistical analysis as it pertains to coral reef monitoring. The guidelines in this appendix, which assume a basic knowledge of statistics, are based largely on Zar (1984) and Green (1979). References are listed at the end of this section. If possible, consult a statistician or field biologist/ecologist with familiarity with experimental design before you begin your monitoring program.

Your Hypothesis

As you formulate your hypothesis, you need to keep in mind the objectives of your monitoring program and the questions you are trying to answer. As Green (1979) points out, "In an environmental study there should be a logical flow: purpose > question > hypotheses > sampling design > statistical analysis > tests of hypotheses > interpretation and presentation of results."

There are a variety of statistical tests you can do with the data you have collected to determine whether you should accept or reject your particular hypothesis, referred to as the null hypothesis (H_o). Your null hypothesis might be that an oil spill caused no decrease in the percent of live coral on a reef flat. The alternative hypothesis (H_a) would be that the oil spill did result in such a decrease.

If you reject the null hypothesis when in reality it is true, you commit a Type I error. Usually a significance level of 5% (α = 0.05) is used to estimate the probability of Type I error. Type II error is the risk of concluding that Ho is true when it is false.

Sampling

How many samples do you need to meet your monitoring objective? For example, how many quadrats should be measured to determine whether sewage flowing over the reef has significantly increased the biomass of macroalgae? If you take too few samples, you won't be able to answer the questions you've raised. However, if you take more samples than you need, you'll be wasting time and money. Also, some sampling techniques can damage reef organisms and should not be done more often than necessary.

The number of samples you'll need depends on three factors:

- the level of precision you want (e.g., the precision of the sample mean is the closeness with which it estimates the true mean of the entire population);

- the degree of confidence ($1 - \alpha$) you want (e.g., 0.95 would give you a l-in-20 chance of concluding incorrectly that you have estimated the mean within the specified level of precision); and

- the variability in the population(?), estimated from a preliminary sample.

There are many formulas you can use to determine the number of samples required and the resulting confidence interval, but certain general principles apply in most situations. For example, the higher the degree of confidence and the more variable the population, the more samples you'll need to take. Similarly, precision increases as sample size increases. For many purposes, a precision of < 10% of the mean is required. At the desired Type I error level ($\alpha = 0.05$), the estimated sample mean would then have a 95% chance of being within 10% of the true mean.

The confidence interval indicates the range within which the true population mean (or other parameter) will fall, given the specified degree of confidence. For example, with a confidence level of 0.95, a confidence interval of $\{17.5 \leq x \leq 20.5)$ would indicate that the true population **mean** lies somewhere between 17.5 and 20.5, 95 % of the time. The more variable the population, the wider the confidence interval.

It's also possible to calculate the number of samples required to determine a significant difference in the means of two independent samples (two-sample test). You'll need to know the expected variability of your data, the significance level, and the power of the test (1-p).

A software program run within a Lotus l-2-3 worksheet is available to calculate the minimum number of samples you should take, and to graph high, mean, and low standard error versus number of samples. See Bros and Cowell, 1987.

Analysis of Variance

Many statistical tests involve analysis of variance (ANOVA). In general, ANOVA provides a way of determining if means from three or more samples differ significantly from each other. "Repeated measures ANOVA" is appropriate if you are interested in determining if there is a significant difference among mean values for three or more samples obtained from permanent quadrats or transects on several different occasions.

If ANOVA indicates a significant difference in means among groups, multiple comparison tests are performed to identify which means differ significantly from each other. Note that the changes you detect are representative only of your fixed study sites and may or may not reflect general changes for the entire reef.

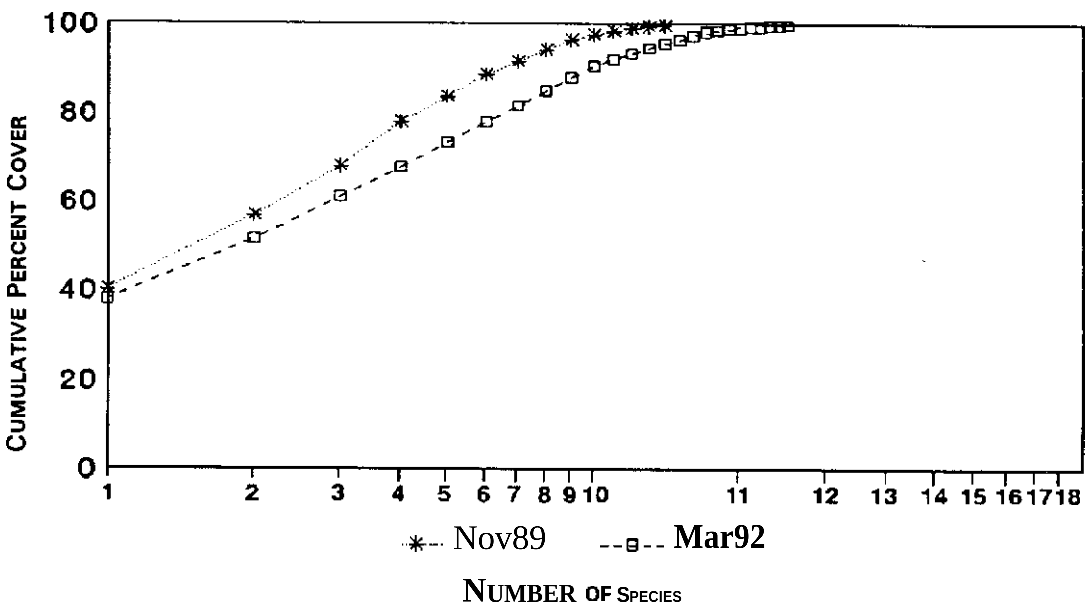
If you wish to compare two sets of samples where there is a relationship between one data point in the first sample and a corresponding one in the second sample, use a paired t-test. For example, you could use a paired t-test to look at differences in percent cover of the dominant species in permanent transects before and after a hurricane or other stress.

ANOVA and paired t-tests are examples of parametric tests. Non-parametric tests are used when your hypothesis does not involve a population parameter (e.g., the mean or variance) and when the assumptions required for use of parametric procedures are not met. For example, ANOVA assumes that samples have been drawn from populations that have normal distributions and equal variances. Many types of ecological data do not conform to these assumptions. An inherent assumption of non-parametric statistics is that different groups have similar distribution. Visual census data on reef fishes collected with the Bohnsack method can be analyzed using non-parametric tests such as the Mann-Whitney U test.

K-Dominance Curves

Univariate measures (e.g., percent cover, Shannon diversity H') have been shown to be less sensitive than multi-dimensional scaling and certain graphical descriptors (k-dominance curves) in detecting changes in coral community structure over time. K-dominance curves, which may be used to show differences in species diversity of two or more samples, are independent of any bias towards species richness or evenness, a problem which affects combined indices such as H'.

Example of K-Dominance Curve



To create a K-dominance curve, you calculate the percentile abundance or cover by rank in descending order, with the most abundant species first. Comparing the curves over time or among samples taken at different sites may indicate changes in ranking or the status of species richness. Graphs in which the curve is lower than the baseline imply increased diversity; if the curve is higher than the baseline, the diversity in the sample has decreased. Non-intersecting k-dominance curves indicate a difference in species diversity of two samples, with the upper curve representing a less diverse sample. (See Lambshead et al. 1983, Warwick et al. 1990, Warwick and Clarke, 1991).

Multivariate Analyses

Multivariate analyses are another way to evaluate time series of data sets. Examples of multivariate techniques include classification analysis, multi-dimensional scaling, principal component analysis, and ordination. In the classification technique, data from all samples are compared; a matrix is generated of similarity or dissimilarity among the data sets. Another procedure in classification produces a dendrogram which geographically classifies the stations in a descending hierarchical order. These techniques are useful in detecting patterns of change or stability. Many of the rigid assumptions of parametric statistics are difficult to achieve in fixed station monitoring programs, thus the non-parametric and multivariate analyses are strong tools to tease apart the dynamics in the systems.

The Community Analysis System is a PC-based software program that can create simple hierarchial species abundance tables, species area curves, K-dominance curves, or sophisticated dendrogram graphics. It is available from: Ecological Data Consultants, Inc. P.O. Box 760, Archer, Florida 32618.

References

Bros, W.E., Cowell, B.C. (1987) "A technique for optimizing sample size," *Journal of Experimental Marine Biology and Ecology,* 114:63-71.

Daniel, W.W. (1978) *Applied Nonparametric Statistics,* Houghton Mifflin Company, Boston, 510 pages.

Green, R.H. (1979) *Sampling Design and Statistical Methods for Environmental Biologists*, John Wiley & Sons, New York, 257 pages.

Lambshead, P.J.D., Platt H.M., Shaw, K.M. (1983) "The. detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity," *Journal* of *Natural* History 17:859-874.

Ludwig, J.A., Reynolds, J.F. (1988) *Statistical* Ecology: A *Primer on Methods and Computing*, John Wiley & Sons, New York, 337 pages.

Peterman, R.M. (1990) "Statistical power analysis can improve fisheries research and management," *Canadian Journal of Fish and Aquatic Science* 47:2-15.

Sokal, R.R., Rohlf, F.J. [1981]) *Biometry*, 2nd edition, W. H. Freeman &Co., San Francisco, 859 pages.

Warwick, R.M., Clarke, K.R., and Suharsono (1990) "A statistical analysis of coral community responses to the 1982-1983 El Niño in the Thousand Islands, Indonesia," Coral *Reefs* 8(4):171-179.

Warwick, R.M., Clarke, K.R. (1991) "A comparison of some methods for analyzing changes in benthic community structure," *Journal of the Biological Association,* United Kingdom 71:225-244.

Zar, J.H. (1984) *Biostatistical Analysis*, *2nd* edition, Prentice Hall, New Jersey, 718 pages.

Appendix C: MATERIALS AND SUPPLIERS

Suppliers and Catalog Companies		Supplies
Forestry Suppliers, Inc. 205 West Rankin Street P.O. Box 8397 Jackson, MS 39284-8397 Phone: l-800-647-5368 (U.S.) (601) 354-3565		Steel survey stakes, fiberglass tape measures, vinyl flagging, clipboards, compasses, Secchi disks, labware, sample bags
Hamm's Spectrum Art Supply 1756 Central Avenue St. Petersburg, FL 33712		Faber-Castell graphite pure 2900 HB pencils
Ryan Recorder 8801 148th Avenue NE P.O. Box 599 Redmond, WA 98073-0599 Phone: l-800-999-7926 Fax: 206-883-3726	Hugron Skipholti 50c Rezkjavik Iceland Fax:354-1-689061	Thermistors
Martek Instruments, Inc. P.O. Box 97067 3216-O Wellington Court Raleigh, NC 27624-7067 Phone: (919) 790-2371 Fax: (919) 790-2375		Transmissometers, multi-parameter water quality meters
Hydrolab Corporation P.O. Box 50116 Austin, TX 78763 (512) 255-8841 l-800-949-3766		Multi-parameter water quality meters
Ben Meadows Company 3589 Broad Street P.O. Box 80549 Atlanta, GA 30366 l-800-241-6401		Nalgene waterproof paper, vinyl flagging, fiberglass tape measures, sledge hammers, field books
47th Street Photo 455 Smith Street Brooklyn, NY 11231 l-800-221-7774		Film in bulk quantities, cameras, electronics, computers

Suppliers and Catalog Companies		Supplies
Fisher Scientific 711 Forbes Avenue Pittsburgh, PA 15219 (412) 562-8300		Labware, balances, microscopes, centrifuges, conductance/salinity meters, Whatman filters
Hach Chemical Company P.O. Box 389 Loveland, CO 80539 1-800-227-4224		Hach kits for bacterial cultures
Turner Designs 845 W. Maude Avenue Sunnyvale, CA 94086 Phone: (408) 749-0994 Fax: (408) 749-0998		Nephelometers, fluorometers
Global Computer Supplies 1050 Northbrook Parkway, Dept. 44 Suwannee, GA 30174		Computer supplies
Goldberg's Marine 201 Meadow Road Edison, NJ 08818 1-800-BOATING	West Marine P.O. Box 50050 Watsonville, CA 95077 1-800-538-0775	Boating and marine supplies
Millepore Corporation 80 Ashby Road Bedford, MA 01730 1-800-221-1975		Filters, filtering equipment
Thomas Scientific P.O. Box 99 Swedesboro, NJ 08085-0099 (609) 467-2000		Lab instruments and supplies, microscopes, vacuum pumps, thermometers, glassware, balances, refractometers, fluorometers, oxygen meters
McMaster-Carr Supply Company P.O. Box 4355 Chicago, IL 60680-4355		Nylon tags to mark coral colonies

For other suppliers of items for underwater use, see: *The Underwater Catalog:* A Guide *to Methods in Underwater Research* (1990), by J. Coyer and J. Witman, Shoals Marine Laboratory and New York Sea Grant Program, Cornell University, Ithaca, New York.

APPROXIMATE EQUIPMENT COSTS (1994)

Installing Markers

Hydraulic systems for drilling	$5,000
Stainless steel tubing	$5 a foot
Survey stakes (30" long)	$124 for 10 stakes

Physical and Chemical Monitoring

Instruments to measure temperature, salinity, dissolved oxygen, pH and conductivity	$1,600 - $7,200
Hugrun Seamon thermistor	$1,300
Ryan Thermistor and underwater case	$752
Ryan "Windows"	$200
Microsoft "Windows" software	$86
Pneumatic tools	$100
GPS (Global Positioning System)	$1,000 and up
Turbidimeter/Nephelometer	$600
Light Transmissometer	$8,000
Li-Cor quantum meter	$1,400 - $2,000
Spectroradiometer	$16,000
Dissolved oxygen meter	$500 and up
Refractometer	$400
pH meter	$60 - $1,600
Centrifuge	$400 and up
Fluorometer	$3,500 and up

Hach kit	$30 and up
Secchi disc	$115
Spectrophotometer	$4,400 and up

Biological Monitoring

Clipboard	$2
All-weather field book	$13
Underwater slate	$10
Graphite pencil	$2
Mylar sheets	$0.50
Fiberglass tape measure (50 m)	$45
" " " (100 m)	$100
Number coded nylon tags	$1 each
Vinyl flagging (150' roll)	$1.35
Sledgehammer (2-lb.)	$14
" (4-lb.)	$20
Nikonos V camera with strobe and 28-mm lens	$1,500
15-mm lens for Nikonos camera	$1,000
Nikonos SLR with strobe and zoom lens	$7,000
Construction of basic monopod or quadropod	< $100
Sony Handicam Super High 8mm video camera	$1,300

Appendix D: LIST OF REVIEWERS

Bill Alevizon
Caribbean Conservation Corporation

Donald K. Atwood
Ocean Chemistry Division
Atlantic Oceanographic and
Meteorological Laboratory, NOAA

Paul Bartels
Department of Biology
Warren Wilson College, North Carolina

Jim Beets
Department of Biology
University of Richmond, Virginia

Gigi Beretta
Australian Institute of Marine Science

Jim Bohnsack
National Marine Fisheries Service
Miami, Florida

David Booth
Australian Institute Marine Science

John Bythell
University of Newcastle-upon-Tyne
Center for Tropical Coastal
Management Studies

Kalli De Mayer
Bonaire Marine Park

Mary Falconer
The Nature Conservancy

Alan Friedlander
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University of Hawaii, Honolulu

Ellen Gorman
National Biological Survey
Virgin Islands National Park

Robert B. Halley
U.S. Geological Survey
St. Petersburg, Florida

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Miami, Florida

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Eastern Caribbean Center
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Virgin Islands National Park

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University of Virgin Islands

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Caribbean Natural Resources Institute

Kathleen Sullivan
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Craig Tobias
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St. Thomas, USVI

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Hato Rey, Puerto Rico

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University of Puerto Rico-Mayaguez

Nicholas Wolff
University of Rhode Island