CORAL REEF MONITORING METHODS

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Introduction

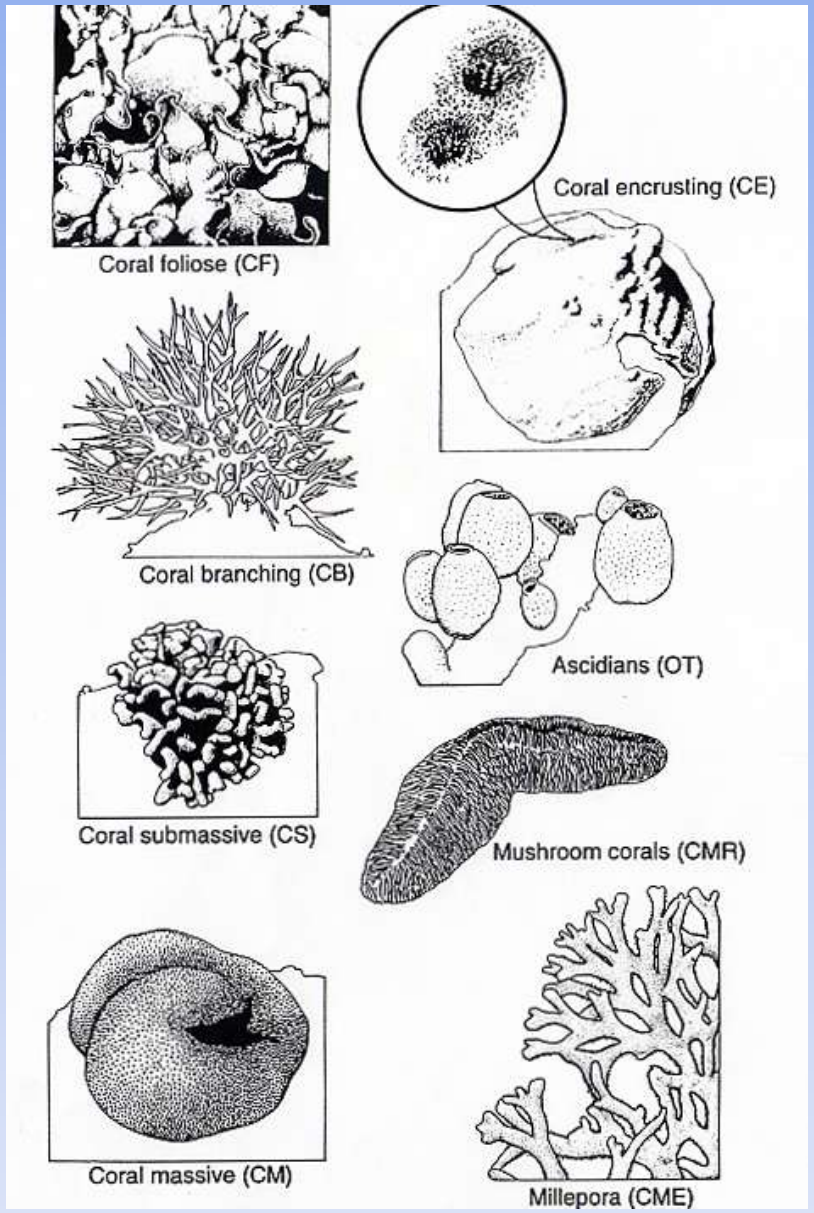
- Surveying & monitoring – key principle
  - Typically use transects & quadrats – but why?
  - Must quadrats be square, must transects be straight?
- Experimental design & statistics
  - Typically looking for significant differences between times or places
  - Or for significant trends in abundance
- Marine methods (protocols)
  - originally adapted from terrestrial ones
  - often more suited site-specific scientific studies
- Marine conservation and management tends to need methods
  - practicable in the marine or coastal environment
  - cost-effective in terms of information gain per available time (especially where time available limited by use of SCUBA)
  - usable by staff with simple gear or limited specialist qualifications
- Also require methods
  - suitable for use over very large areas (of coastline or sea-bed)

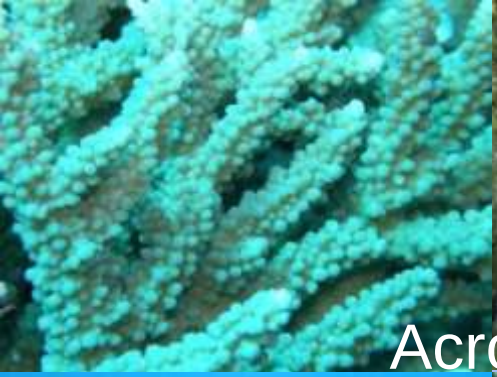
Problems Measuring the Amounts of Coral

- Colonies vary greatly in size and shape and often fragment into semi-separate colonies, so you can not simply count them
- Quantitative methods attempt estimate percentage cover of substrate **(coral cover)** by different coral species, and by other substrate types (reef rock, algae, encrusting organisms)
- Planar area of corals as viewed from above usually adopted as measure of abundance, but not in all methods
- Are several difficulties with approach:
  - Exact measurement complex shape difficult e.g. For branching corals: how to cope with gaps between or layering of branches?
  - Relationship between area of coral viewed from above, and actual surface area also varies greatly with growth form
  - Methods have been tried (wrapping in foil, absorbing dye) but provides estimate only for typical specimens of particular size (diameter)
  - Even if could estimate surface area of coral biomass of tissue per unit area varies with hugely with genus

Identifying Corals

- Identification of less common genera difficult, & identification to species very difficult, especially nderwater
- May be 200-300 spp. in region; Caribbean easier, only about 40 spp.
- Much work done to genus level only
- Often less qualified staff record only *growth-forms* or *life-forms*, despite not corresponding with genus or family identification
- In last decade ease of taking good underwater images has greatly eased identification to genus or species
- Recent digital or on-line identification guides further assist cf:
  - http://www.coralsoftheworld.org





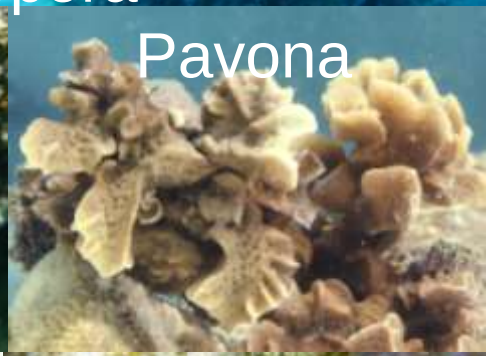
Acropora

Acropora

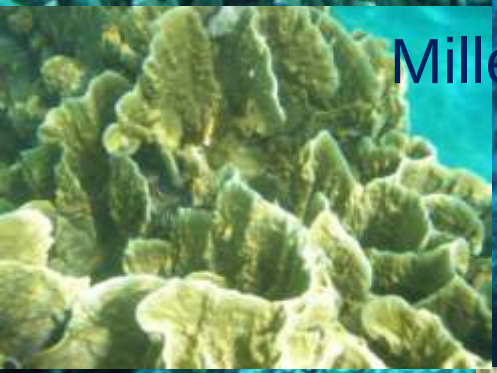
Acropora

Stylophora

Pocillopora



Pavona



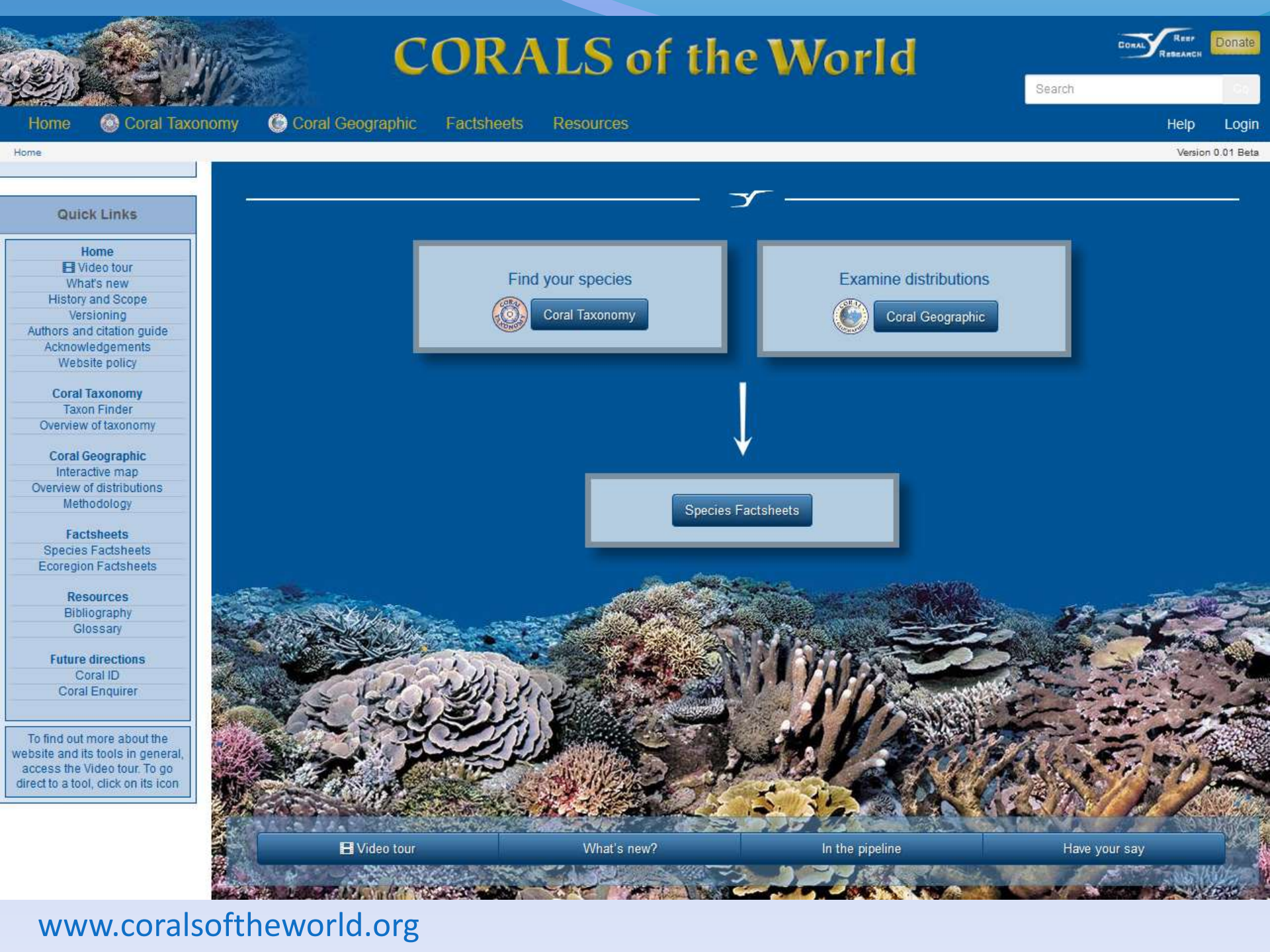
Millepora

Turbinaria

Coscinarea

Fungia

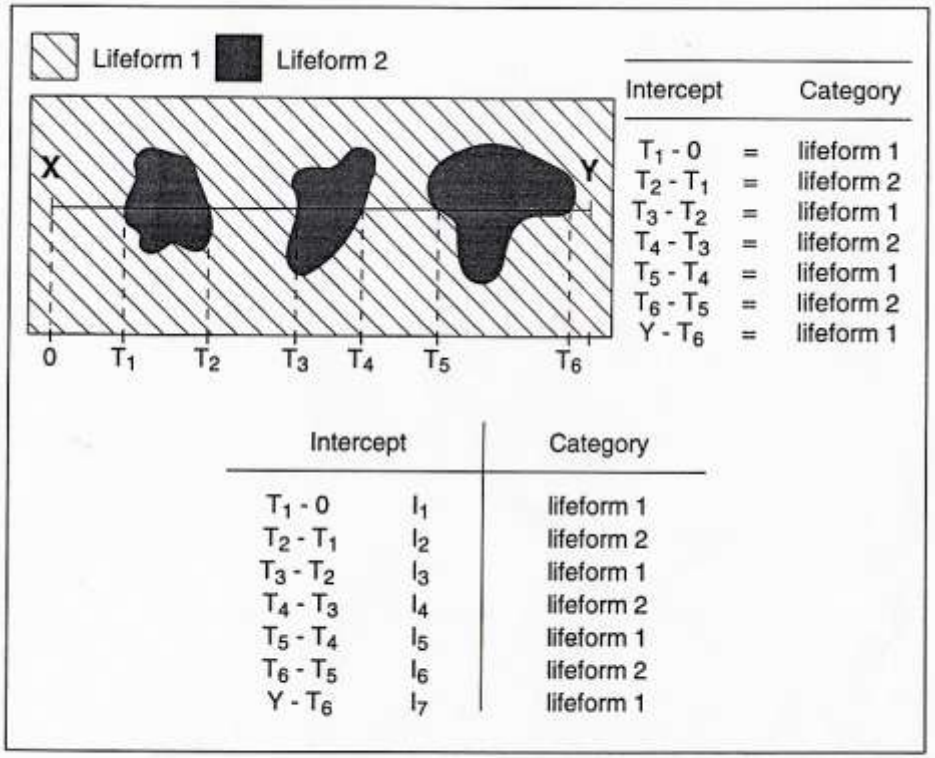
Montipora



www.coralsoftheworld.org

Line Intercept Transects (LIT)

- Most widely used method is *Line Intercept Transect* (LIT) introduced by Loya (Loya & Slobodkin, 1971).
- Distance of draped line across each successive coral or different type of substrate is recorded.

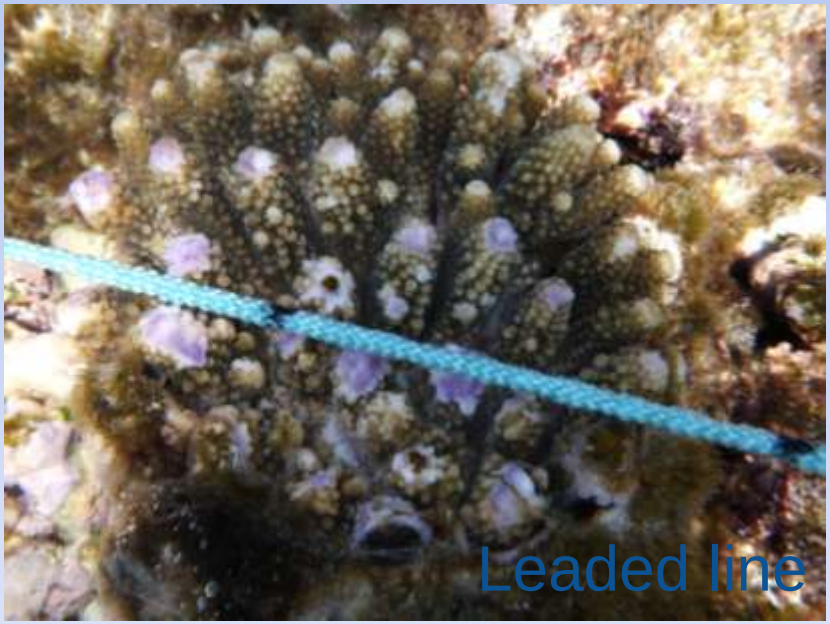


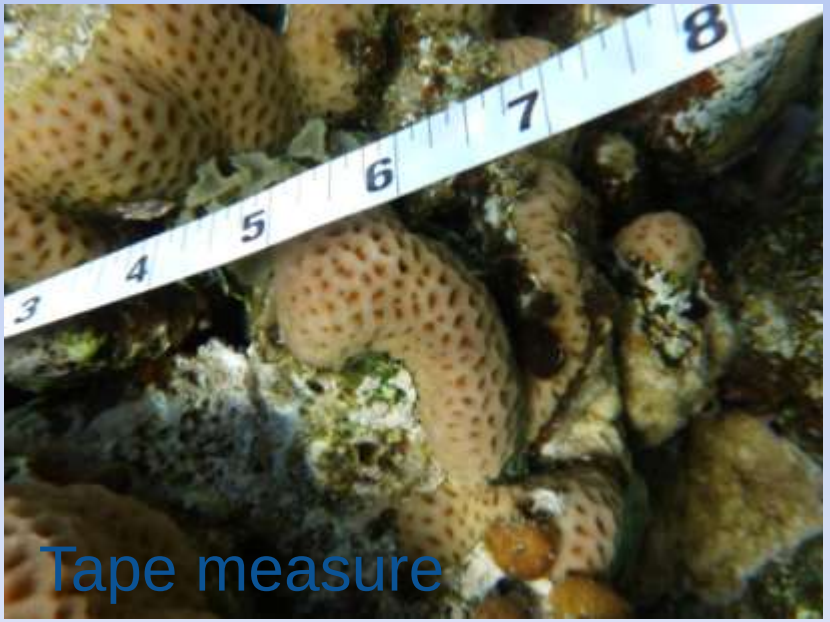
Intercept		Category
$T_1 - 0$	I_1	lifeform 1
$T_2 - T_1$	I_2	lifeform 2
$T_3 - T_2$	I_3	lifeform 1
$T_4 - T_3$	I_4	lifeform 2
$T_5 - T_4$	I_5	lifeform 1
$T_6 - T_5$	I_6	lifeform 2
$Y - T_6$	I_7	lifeform 1

Intercept		Category
$T_1 - 0$	=	lifeform 1
$T_2 - T_1$	=	lifeform 2
$T_3 - T_2$	=	lifeform 1
$T_4 - T_3$	=	lifeform 2
$T_5 - T_4$	=	lifeform 1
$T_6 - T_5$	=	lifeform 2
$Y - T_6$	=	lifeform 1

Figure 2.23 Schematic diagram of a transect (XY) showing the transition points (T) for each lifeform crossed by the transect. The difference between consecutive transition points is the intercept of the lifeform.

- Transect lines usually run horizontally (parallel with shore) at series of different depths.
- Transect length: 10m used by Loya (based species/length curve) widely copied, but in most areas 30 m plus required
- Loya used light chain which drapes over corals; leaded-line is better, heavy enough, but not damage corals.
- Measuring tape or light rope does not rest on substrate and is wafted by waves, or if stretched does not rests on substrate.


Leaded line



Tape measure

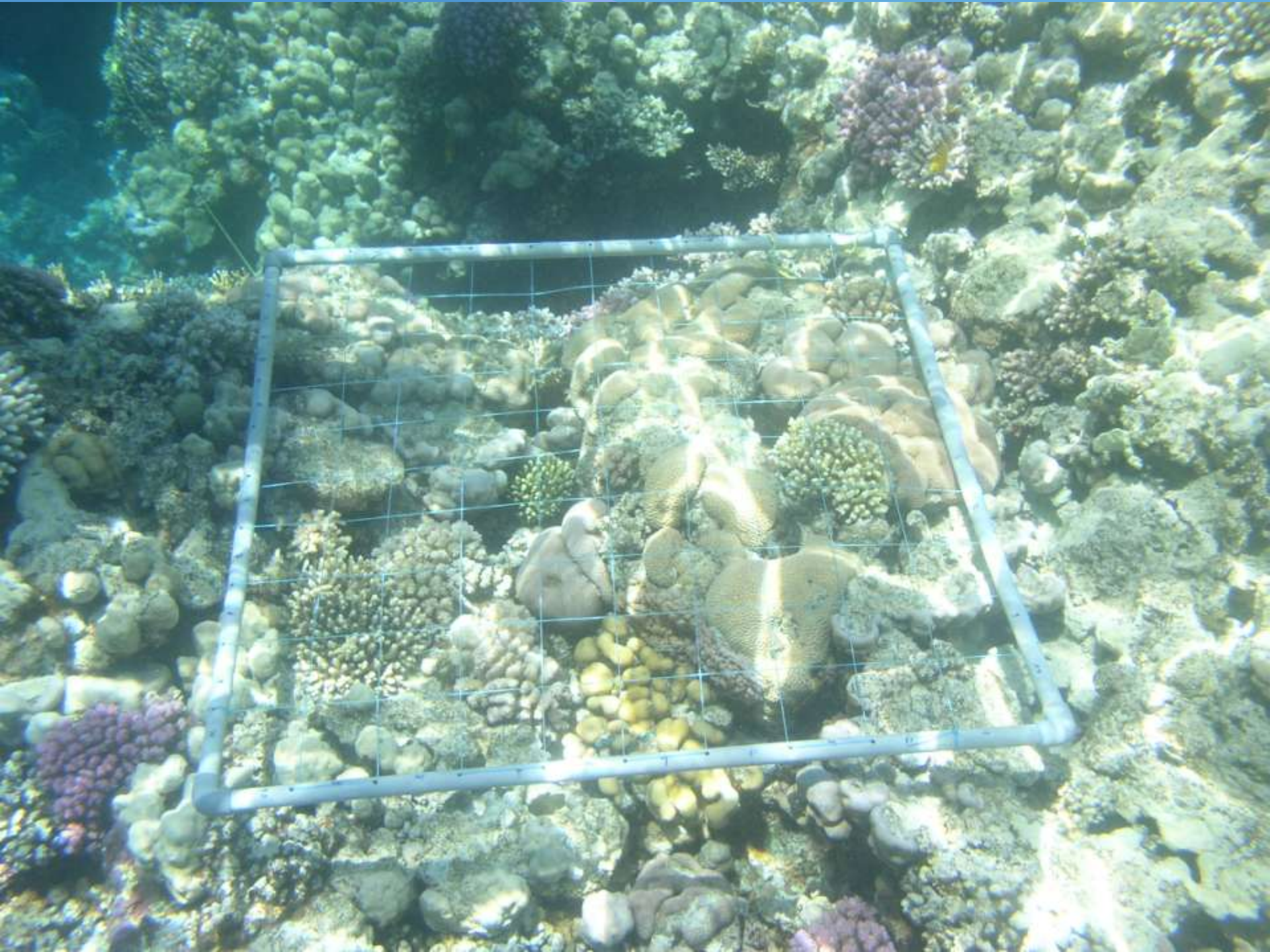
Advantages & Disadvantages

- Assists with problem of complex topography of reefs and corals, and issue of estimating planar area.
- Principle simple, repeatable by different observers, provided line is stable and runs on substrate.
- **BUT**
  - Difficult to position line without bias; even if end positions chosen randomly. Easier to avoid bias if use zig-zag route.
  - Gives different cover estimate compared other (e.g. quadrat) methods.
  - Often difficult to determine exactly what is under tape if not touching substrate, notably on slope or steep face
  - Almost impossible to re-position transect along exactly same line for monitoring purposes.
  - Markers or pins at intervals not really solve problem, as is time consuming to insert & divers damage corals while doing it.
  - Area sampled (data gained) per transect length is very low, and S.E. per unit length correspondingly very high.

Quadrat Methods

- Quadrats generally 1m^2, but may be 2 x 2m, or 5 x 5m or larger, ornow often 0.25 or smaller
- Quadrat size chosen partly depends coral abundance
- Various methods for determining actual coral cover:
  - Rough estimation by eye, sometimes by reference small number (4-16) subdivisions (e.g. Bouchon, 1981)
  - Careful measurement by eye, i.e. subdivision by subdivision within large number subdivisions (typically 100 within 1 x 1 m^2 quadrat)
  - Accurate drawing of quadrats showing all colonies (e.g. Mergner & Schumacher, 1974), very time consuming.
  - Photography, usually colour (though originally B&W!) but still often very difficult to distinguish some substrates, let alone species.
  - Stereo photography (Done, 1981) makes species & substrate identification easier
  - Areas of corals can be measured off photographs manually or by computer using image analysis software, though time-consuming
  - Sampling of sufficient number of points within each photo-quadrat probably most efficient method and has now become standard

photos on next 2 slides



Advantages & Disadvantages

Quadrats much better suited to monitoring:

- Much easier to re-locate
- Can follow changes over time to specific corals
- Adjacent quadrats sample only restricted area
- Were time-consuming to record fully, but

Especially suited to recording by photographs (photo-quadrats)

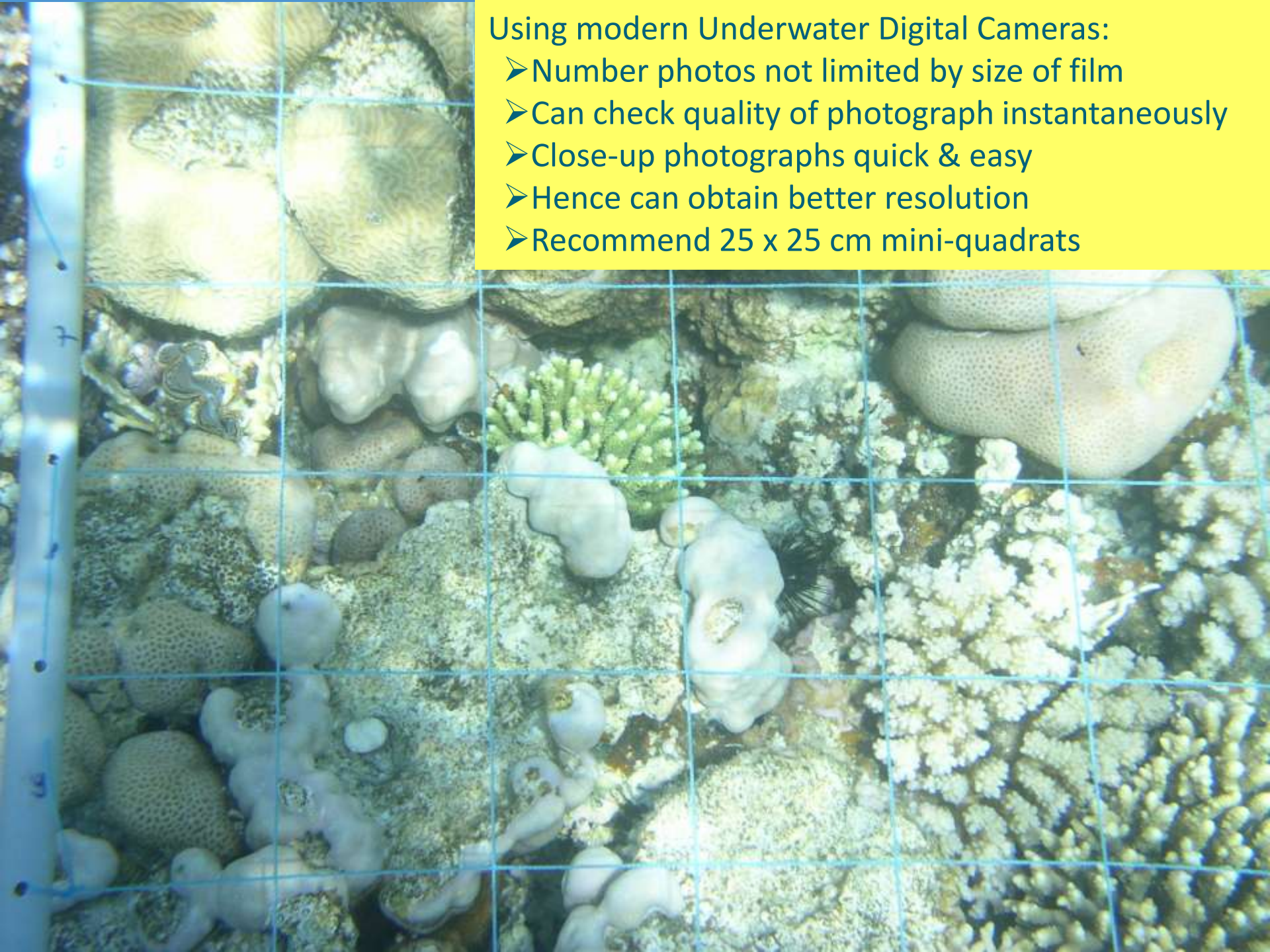
- Photographs can if necessary be analysed or re-analysed much later
- Photographs may provide evidence for causes of change e.g. disease
- Photographs provide visible evidence to non-divers / administrators

However, note:

- Exact angle at which photograph taken will influence results
- In many photographs cryptic / encrusting corals can not detected or distinguished from substrate; best to take detailed notes at time
- In photos many corals can not be identified to species or even to genus

Latest generation digital cameras solve some of these problems

(see next slide)



Using modern Underwater Digital Cameras:

- Number photos not limited by size of film
- Can check quality of photograph instantaneously
- Close-up photographs quick & easy
- Hence can obtain better resolution
- Recommend 25 x 25 cm mini-quadrats

Point Transects

- Simple point method records coral species or substrate beneath series of points along transect.
- Reefcheck (international project) uses 0.5 m intervals.
- Seems simpler & quicker (in terms distance covered) than LIT.
- Has most of the disadvantages of LIT.
  - Determining exactly what is under point can be very difficult
  - Especially difficult to apply on steep slope
  - Problem in relocating points makes of little value for site monitoring
  - Samples very small area & collects very little information per unit length
  - However, can pool numerous replicates to detect e.g. regional change

Plotless Methods

- Determine distance to coral (& its size) nearest to series of points along transect
- Point-quarter method only variant used much on reefs, record nearest coral in each of 4 directions
- Cover calculated as total area of corals, divided by square of mean distance from the points to the corals
- Avoids problem of most samples being empty when abundance /coral cover is very low
- Good for studies of individual species or corals suffering specific impacts e.g. disease

Video-photography

- Video-transects increasingly used as underwater HD video now very affordable
- Quick to take large amount of data, which can be analysed later

BUT

- Resolution markedly less than when taking still photographs
- Very awkward on irregular substrate, better in Caribbean or Arabian Gulf
- As with LIT, difficult to relocate and repeat (i.e. for monitoring)

- Usually analyse still frames at intervals - data thus comparable to series of spaced quadrats
- Use point sampling within the frame
- Very useful for recording general habitat appearance

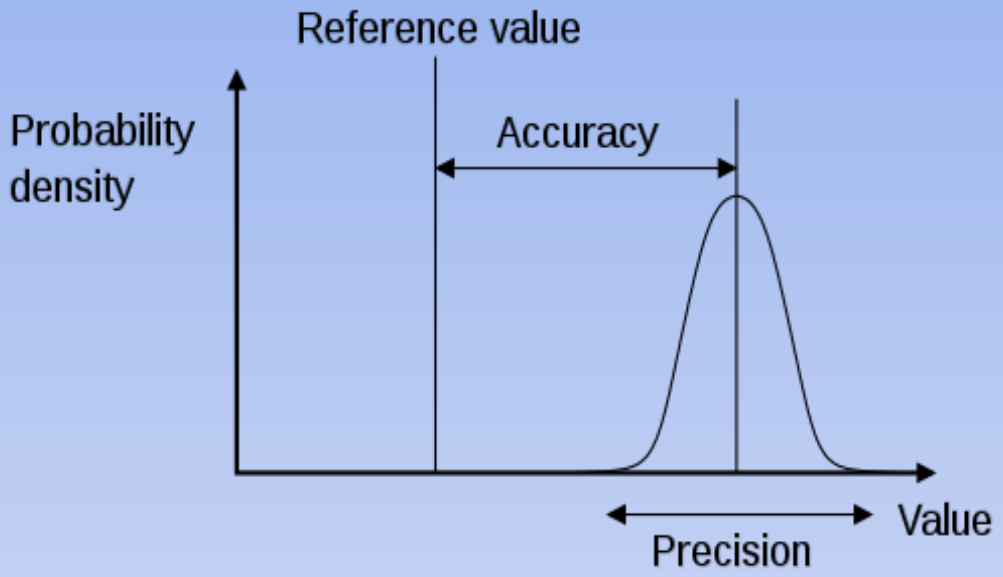
Sampling Strategy

How many transects do I have to do? And where??

- *A priori* arrangement of transects or quadrats might be **random, systematic, stratified (-regular), or stratified-random**
- Reefs have a marked zonation linked to depth (and light), therefore random location of quadrats or transects can by chance give completely wrong result
- Stratified-random distribution (or stratified-regular) solves this problem and is appropriate
- Main reason for random sampling is to avoid observer bias – if can avoid this then regular sampling may be acceptable
- For monitoring and management a systematic/regular arrangement provides representative cover of whole area and is much easier to implement
- If area very large sampling affected by travel time (especially underwater) - best option often clustering of samples at series of stations (Cluster Sampling – may be 2- or 3- level).

Accuracy vs Precision

- Natural patchiness or variability of ecological communities makes exact mean values (e.g. of coral cover) very difficult to determine
- Needs large number of replicates to allow for variability between samples
- Recording many replicates more important than vary exact



- If wish to monitor or compare areas, the key issue is **Precision**, rather than **Accuracy**,
- Precision is Standard Deviation / square root of number of samples = SD/ √n
- Need is to maximise gain in Precision per unit time

Comparison of Methods

Leujak & Ormond compared **accuracy and precision, and time- and cost-efficiency** of 6 methods: mapping of 1×1 m quadrats (MAP), line-point transect (LPT), line-intercept transect (LIT), video sampling (VIDEO), photo-quadrats 1 x 1 m^2 analysed by point-sampling (PQ-P) and photo-quadrats 1 x 1 m^2 analysed by outlining coral colonies (PQ-S)

Precision: Power analysis indicated that the sample sizes required to yield an 80% chance of detecting even a 20% difference in total hard coral cover (e.g. between sites or times) much greater than normally used:

- 22 mapped quadrats
- 1150 points for LPT
- 135 m of LIT
- 95 frames with 5 points for VIDEO (say 150 m transect)
- 64 photo-quadrats for PQ-P or PQ-S

Much greater sample sizes required to detect differences in cover of individual growth forms or taxa, or differences of 10% (or less).

Relative cost-effectiveness in terms of time required to estimate total coral cover to required precision:

- VIDEO > PQ-P > LPT > PQ-S > LIT

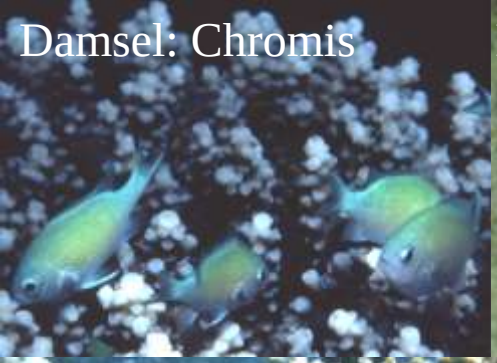
Rapid Appraisal

- In conservation work usually limited manpower / resources hence need to assess status of site in e.g. single visit or dive
- Depend on qualitative / semi-quantitative assessments
- Increase ground covered by using Manta Board or Underwater Scooter
- Subjective assessments notoriously inaccurate due parallax and psychological factors – inexperienced observers often estimate twice true value
- Different schemes based subjective assessment often use 4 or 5-point scales (though I now use non-linear 10-point scale)
- Training and use of “mental protocol” critical for reliable estimation
- Need good protocol e.g. assess different reef zones separately
- Need carefully designed proforma to ensure all relevant information noted

UNDERWATER VISUAL CENSUS OF FISHES (UVC)

INTRODUCTION

- now widely used in ecological & conservation studies
- agreed fairly accurate for non-cryptic, diurnally active spp.
- precision estimated from repeat transects at 23-37%
- also used because non-destructive and traditional fisheries methods not permitted or practicable
- can record habitat /substrate at same time
- several detailed reviews e.g. Harmelin-Vivien et al (1985) and Bortone & Kimmel (1991)


Damsel: Chromis


Damsel: Sergeant-Major


Damsel: Dascyllus


Fusiliers


Butterflyfishes


Angelfishes


Wrasses


Lizardfish


Sandperch


Anthias


Hawkfish


Cardinalfish


Parrotfishes


Emperors
Soldierfish
Squirrelfish
Snappers
Surgeonfishes
Goatfish
Groupers
Lagoon Ray
Triggerfishes
Pufferfishes

DIFFERENT METHODS

- transect
  - line (Harmelin-Vivien et al 1985)
  - band (widely used)
  - time (Boyer et al)
- frame count = in fact is a quadrat
- point census (Bohnsack & Bannerot 1986) = circular “quadrat”
  - usually 10 m diameter (5 m if poor visibility)
  - fish present counted over e.g. 15 mins in systematic way
  - small resident / larger vagrants / overall check
- random search (Thompson & Schmidt, 1977, Bortone et al 1986)
  - record species list, sometimes confirming presence every e.g. 10 mins.
  - estimate abundance on semi-quantitative scale (e.g. 1-6)
- structured search
  - structure swim by equalising time in different reef zones
  - 50 mins dive plus 50 mins snorkel over 100m length of reef (RO)
- mapping
  - spot mapping (difficult for > 1 spp at a time)
  - territory mapping with territorial damselfishes & butterflyfishes

BAND TRANSECTS

- diver based-band transects: (AIMS Manual, Reefwatch II & AGRRA methodologies)
  - small spp. (e.g. pomacentrids) or juvs on 30 or 50m x 1 or 2 m
  - large or conspicuous species on longer & wider transects
- single families or Focal Group
  - discrete trophic group censusing proposed following testing in Disney World Living Sea Aquarium!
- **Reefwatch** (RO) recommended: 4 transects 200m long x 10m wide:
  - repeat at 17 m, 10m, on Reef Edge (3m), and on reef flat or in lagoon
  - single observer count single or related families: butterflyfish & angelfish, groupers, snappers & emperors
  - large sample areas of 2000m^2 result in much greater precision
  - length of transect determined partly by logistics: air supply on standard SCUBA tank
  - deeper transect first, due need for decompression

COUNTING FISH ON TRANSECTS

- count fish seen ahead within transect
- avoid counting > once, by noting size, number, peculiarities of individuals
- eye roves from side to side or diver meander from side to side
- strategies of searching required for some families e.g. groupers under overhangs

COURSE & LENGTH OF TRANSECT

- shorter transects for smaller fish, can lay transect as for corals
- with longer transects laying line very awkward
- larger fish scared by laying line, small fish may be attracted
- swim along contours using depth gauge
- place vertical marker lines down reef or record actual distance with GPS

EFFECT OF TRANSECT WIDTH

- wide transects underestimate density because miss individuals (Sale & Sharp, 1983)
- but narrow transects over-estimate density because of increased "**edge effect**"
- 1 or 2 m wide transects - check distance with transects pole
- with wider transects estimate by eye, when is likely source of error
  - train on land and in water to recognise 5 & 10m distances
  - lay 10m line at beginning & end of transect
  - Potential use laser range finder

DISTANCE SAMPLING / TRANSECT

- can record fish in 2 bands: 0-5 and 5-10m, or estimate actual distance
- helps reduce temptation to include near misses
- can use to correct statistically for decreasing proportion seen with distance

SPOT OR CIRCLE COUNT

- stationary diver counts fish within
  10 m diam. circle (Bohnsack)
- standardise time usually 15 mins each, thus 3 circles per dive
- structure 5 mins for obvious residents, 5mins for species entering, & 5 mins final detailed search
- smaller circle in turbid water e.g. 5 m diam (Kimmel, 1993)
- advantages if:

  want to record abundance of all species, though requires specialist knowledge

  diver is limited to small area, e.g. near dive boat

  want detailed record of substrate to relate to fish present

TRAINING

SPECIES IDENTIFICATION

- noticing and identifying species is critical
- thorough training and testing is critical to achieve good data
- train from books, slides, videos & in field
- specialising in few families eases training, assisted by UW ID cards
- testing used to assess reliability of divers and reject doubtful data

SIZE ESTIMATION

- size estimates greatly increase value of survey, providing information about status of stock

  larger species (e.g. groupers) estimate to nearest 5 or 10 cm

  medium/small spp. classify as j (juvenile), $^{1}/_{4,}$ $^{1}/_{2}$ $^{3}/_{4}$ 1 and 1+
- objects appear 25% bigger OR 25% closer underwater
- less experienced divers tend over-estimate, but experienced divers tend to underestimate, especially with large fish
- Training (using models or sticks) generates dramatic improvement

REEF INVERTEBRATES

- Common macro-invertebrates usually counted along short (10 – 50 m) band transects
- Can use same band transect as for small fish and coral photo-quadrats
- Typically swim along transect with 1m pole to check distance of animals from
  - 2m wide (1m to either side of line) for urchins, giant clam and large gastropods
  - 1m wide (to just one side of line) for e.g. medium-sized molluscs
- Crown-of-thorns: can search for feeding scars)(not the animals themselves) over 200m x 10m band transects
- Monitoring over wide areas: search for groups of scars over large areas using manta board or scooter or free search
- Small invertebrates best estimated by detailed sampling (cores or quadrats) at intervals along transect
- Many invertebrate species very patchy distribution

CONCLUSIONS

- Preferred method varies with question asked, logistics, gear and staff available.
- Depends on purpose of study: broadscale conservation survey vs quantitative academic research
- Also depends on whether monitoring over time required
- Quantitative methods differ in time-efficiency with which they generate sufficient data to achieve a required level of precision
- Important to test whether the sample sizes planned have the ability to detect differences of the size expected (power analysis)
- Do not just copy method that seems most fashionable!