On-site fish assemblage analysis, experimental fishing methods and performance evaluation

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The artificial reef (AR) is assessed for its performance after deployment. The biomass, diversity, abundance etc. of fishes associated with AR after colonization is analysed through different methods. They are direct observation, remotely operated vehicles (ROVs) inspection, fishing gears and acoustic methods. No single method gives accurate inputs but combination of two or more methods ensures a better measure of the performance of AR. Various sampling methods and data analytic methods used to assess AR globally are described below.

1. **Direct observation - SCUBA diver survey -** The diving teams record observations on their slate and evaluate over a specified area (10x10 m) while swimming over the reef at good visibility. This method is good for recording general assessments but depends on the diver's knowledge. Data comparisons over time are not easy with this information. However, it is good at picking up strange and interesting occurrences and observations and is also of advantage in conservation, transplant and ranching trials and studies.

   A. **Visual census:** Underwater visual census (UVC) is the primary tool to assess fish assemblage in AR when there is very good visibility. Divers equipped with SCUBA perform counting and measurements and record photographs and videos of fishes in the reefs.

   i. **Strip transect**: The diver swims along a transect of pre-established length in a pre-established time interval. listing and recording all the species encountered.
   ii. **Point count**: The diver stands at a fixed point and enumerates the organisms observed within a prescribed area or volume in a pre-established time interval.
   iii. **Species-time random count**: The diver swims randomly over the survey area for a predefined period either simply recording the species encountered or listing them in the order in which they were initially seen.
   iv. **Combinations of methods**

   The data collected through the visual census is used to estimate the relative abundance of fishes at various reef areas or over the period from a single or a group of reefs and to calculate diversity indices of fishes.
   Advantage: Non-destructive *in situ* method

Disadvantage: As the visual survey is performed during the daytime, chances of biased sampling of diurnally active species are high, leaving out nocturnally active species from the enumeration.

Relative abundance (Odum, 1970)

$$RA = \frac{ni \times 100}{N}$$

Where, ni is the total number of individuals of a particular species and N is the total number of individuals of all species

Fish diversity index

Simpson's dominance index (Harper, 1999)

$D = \sum ni(ni-1)/N(N-1)$

Where, ni is the total number of individuals of a particular species and N is the total number of individuals of all species

Simpson index of diversity

$D' = (1-D)$

Shannon-Weaver diversity index (H')

$H' = -[\Sigma pi(lnpi)]$

Where, H' = Diversity Index; pi= ni /N; where "ni" is the number of individuals collected for a species, and 'N' is the total number of individuals of all species

Species richness (Margalef index, d)

$d = (S-1/Ln\ N)$

Where, S is the number of species and N is the number of individuals in the sample.

Species evenness (Pielou index, E)

$E = H'/LognS$

Where, S is the total number of species and H' is the Shannon-wiener diversity index

B. Quadrat survey: This involves placing a grid over the area being surveyed to either estimate percentage cover or ease the counting of a targeted organism. The size of the grid can vary depending on the goals of the survey, but often a 1m x 1m grid broken into 10 columns and rows is used for divers. The quadrats can either be randomly thrown out, haphazardly placed, or permanent. This is a good method for accurate estimations and counting of small organisms. A photographic inventory will aid more but requires some training, but larger areas cannot be assessed and the studied area should also be least disturbed. Good particularly for invertebrate recruitment and settlement studies.

C. Transect Lines: This is a technique in which a surveyor will lay out a measuring tape, and record all data or observations in relation to that line. The line can be laid out randomly or can be laid in the same place each time using permanent marking points. Surveyors may use multiple short lines, or a single long transect line, depending on their survey design. The transect line survey is the most used technique. The data can be compared and reduces subjectivity and gives better accuracy and a wide range of surveys can be planned. This is an excellent tool for assessment and recruitment studies over the AR sites but needs skilled, trained divers for the same.

D. The Manta Tow method: In this method where a diver with a snorkel or scuba is dragged over a reef for documentation and recording and visual estimates. This is a tool useful for comparative studies between AR and Non-AR sites on time and season scales. Larger areas can be represented and damages to the reef can also be estimated. But possible only in shallow installation areas where visibility is very good. Very rarely employed method.

2. **Remotely operated vehicles (ROVs) inspection -** Remotely operated vehicles (ROVs) are video-based survey tools for quantifying fish assemblages at a range of depths. Relative abundance and fish diversity indices are calculated here as the input data is the same for both direct observation and ROV**.**

3. **Bait fixed ROV -** consists of a steady weight supported stand with a platform holding camera and light settings facing a bait bag hanging in front of the stand for the reef fishes to accumulate. The continuous recording gives information on the seasonal compositions and size variations. This is a good method to understand recruitment and brood stock dynamics in ARs.

4. **Fishing gears/sampling gears employed to sample the fishes in AR -** They are traps, long-lines, hooks & lines etc. Here catch-based sources of data are used to assess the performance of the AR. Catch per unit effort (CPUE) in terms of the number of fish caught per effort and total weight (kg/net or kg/hook) per effort is estimated. In addition, abundance and diversity are also calculated using the equations mentioned above. At times, surface trawl and seine data can be collected if available, to give a comprehensive picture of the sizes, species, and abundance in numbers

$$Catch\ per\ unit\ effort\ (CPUE) = \frac{Total\ catch\ (kg)}{Total\ units\ employed}$$

Advantages: Provides catch/species composition, length-frequency distributions, biological data etc.

Disadvantages: Destruction of AR, gear selectivity - samples of particular length groups may be selected according to the gear type. The traps and trammels can estimate the reef-dwelling populations and particularly give estimates of ornamentals and their abundance and diversity.

5. **Acoustic methods -** Single-beam echosounder, multibeam echosounder, side scan sonar etc. are used to assess fish assemblage at the AR site. The relative fish abundance index, RFAI can be measured from survey transects at each nautical mile-long georeferenced elementary distance sampling unit (EDSU). The EDSU is 200 pings over a 5.5 m depth. The biomass density ρ_i (t/nmi^2, tonnes per square nautical mile) of the i^{th} species in the studied area is calculated by the formula (Simmonds and MacLennan, 2005):

$$\rho i = C_i \times \frac{RFAI}{4\Pi\,\bar{\sigma}} \times \bar{W}_i \times 10^{-6}$$

$$\bar{\sigma} = \sum_{i=1}^{n} Ci \times 10^{TSi/10}$$

$$TSi = 20 logli + b_{20,i}$$

where *ci* is the number percentage of the *i*th species estimated, RFAI is the nautical area scattering coefficient in m^2/nmi^2, $\bar{\sigma}$ is the mean backscattering cross-section in m^2, $\bar{W}i$ is the mean body weight of the *i*th species estimated in *g*, *n* is the total species estimated, *li* is the body length of the *i*th species estimated in *cm*, and $b_{20,i}$ is reduced TS (target strength) in dB (decibel).

TS-L relationships of the fish species can be calculated through different regressions of dominant species available in the literature to estimate the fish length, and the b_{20} values of other species can be adopted from their families.

The fish biomass (B,t) is calculated by the formula:

$$B = \sum_{i=1}^{n} \rho i \times A$$

Where, $\boldsymbol{\rho i}$ is the biomass density of the *i*th species estimated in t/nmi2, *A* is the studied area estimated in nmi^2, *n* is the total species estimated

Advantage: No damage to reef or associated flora and fauna.

Disadvantage: Crustaceans and molluscs cannot be recorded.

Often, a combination of acoustic techniques and fishing gear is also followed.

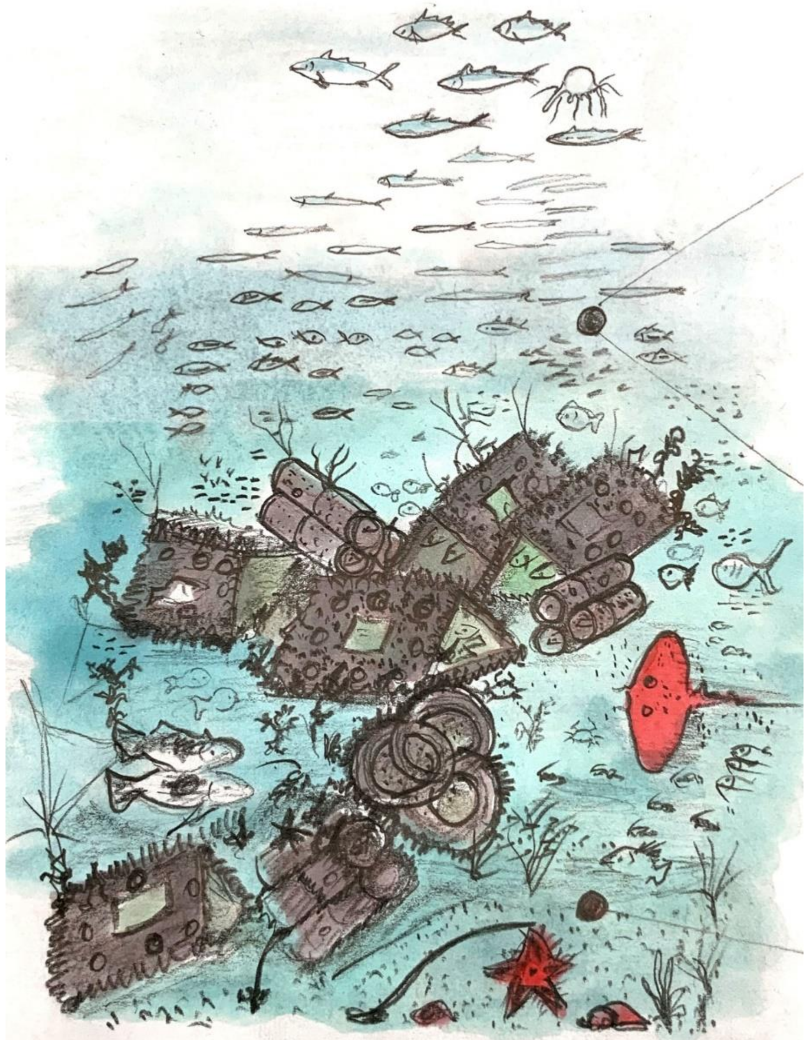

Fig.60. A multitier trophic level fish assemblage and ecosystem as visualized by a fisherman.

Fig.61. An artist's illustration of the AR site monitoring and assessment by divers.

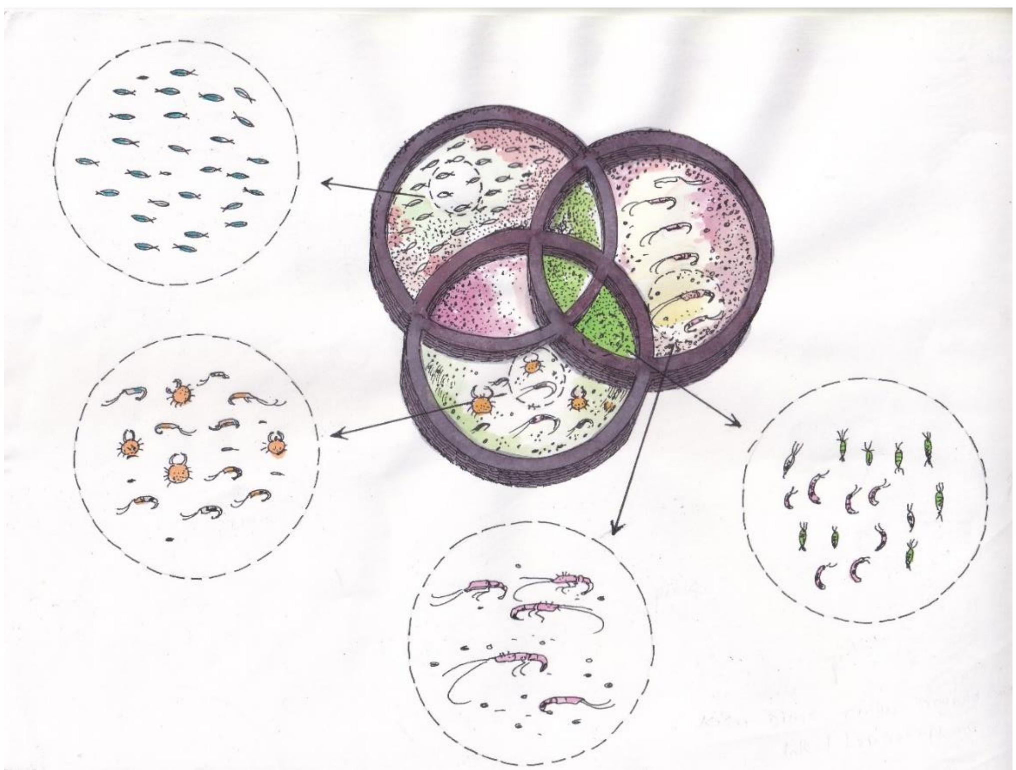

Fig.62. Benthic assemblages in the well ring modules -shrimp, crabs, lobsters, crinoids

Performance evaluation of reefs

Biological productivity indices - **Area of Influence**, **Primary Effective Boundary** and **Secondary Effective Boundary** for a fish caught from reef perimeter (PEB & SEB), **Biological Influence Range** (BIR) and biomass and density of fish fauna can be derived for artificial reef sites. The following indices - equations were developed for assessing the health of the deployed reefs (for the existing material and design by ICAR-CMFRI) in the coastal water of TN from case studies and analysis.

1. **Efficient Life of Artificial Reef (AREL, years)** *for the existing material and design by ICAR-CMFRI*

   AREL (years)= ((%a x0.1) +(%b x0.60) +(%c x1) +(%d x0.03) + (%e x0.005)) x CC x CS x df

   - *where a>3 mm, b=3-2 mm, c=2-1 mm, d<1 and e=clay in percentage composition of sediment texture*
   - *Coefficient of Current velocity = CC (factor values severe = 0.88 (current velocity >0.3 m/s, moderate = 0.95(0.15-0.25 m/s), mild=0.98 (0.1-0.14 m/s) and low =1(<0.5m/s) and*
   - *Coefficient of wave swell = CS (factor values severe = 0.87 (wave energy >6.8-8.5 kj/sqkm, moderate = 0.95 (4.5-6.5 kj/sqkm), mild = 0.98 (0.1-0.14 kj/sqkm) and low* ***= 1 (<0.5 kj/sqkm)***
   - *Df- depth factor (<4 m-0.75-,4-6 m-0.9,6-10 m-0.95,11-20 m-1.1,>21 m-1.2)*

2. **Sinking Rate of artificial reef modules (ARSR, mm/year)** *for the existing material and design by ICAR-CMFRI*

   ARSR (mm/year) = ((%a x1) +(%b x3) +(%c x3) +(%d x0.5) + (%e x 100)) x CC x CS x df

   - *where a>3 mm, b=3-2 mm, c=2-1 mm, d<1 and e=clay in percentage composition of sediment texture*
   - *Coefficient of Current velocity = CC (factor values severe = 1.1 (current velocity >0.3 m/s, moderate = 1.04 (0.15-0.25 m/s), mild=1.02 (0.1-0.14 m/s) and low =1(<0.5 m/s) and*
   - *Coefficient of wave swell = CS (factor values severe = 1.15 (wave energy >6.8-8.5 kj/sqkm, moderate = 1.06(4.5-6.5 kj/sqkm), mild = 1.03 (0.1-0.14 kj/sqkm) and low = 1(<0.5 kj/sqkm)*
   - *Df- depth factor (<4 m-1.5-,4-6m-1.3,6-10m-1.25,11-20m-1,>21m-0.75)*

3. **Performance efficiency of Artificial reef (ARPE)** *for the existing material and design by ICAR-CMFRI and a unit of 250 modules deployed*

   ARPE (%) = (AREL +ARSR x (0.7/100)) x FP x EP x RP x 10

   - *Fishing pressure (FP)-(0.5) heavy (>25 OBM + >trawlers, >others), -(1.1) moderate (15-25 OBM, few trawlers and least others), (1.5) low (10-15 OBM, nil, nil) and (1.8) poor (1-2 OBM, nil, nil)*

- *Estuarine Proximity (EP)-distance from bar mouth – 0.85(<3km), 1.3(3-10km),0.95(>10km) and 1(>20km)*
- *Reef patch or rock Proximity (RP)=distance from the nearest rock or reef patch -1.2 (300-500m),1.1(>500m) and 1(>1km)*

4. **Area of Influence**
   - *Surface and midwater – **200-300 m** from the epicentre of the reef, Benthic and bottom - **1-100 m***
   - *Maximum catches in gill nets from **40-60 m** extending from a periphery of the reef*
   - **Primary Effective Boundary for fish catch from the reef periphery (PEB)**
   - *Pelagic - 200-400 m, Bottom - 40-200 m*
   - **Secondary Effective boundary for fish availability from the reef periphery (SEB)**
   - *Pelagic- 400-600 m, Bottom - 200-300 m*
   - **Biological Influence range *(BIR)- 40-60 m***