Original Research Article

Potentials of establishing sentinel integrated reef ecosystem in Eastern Coast of Bicol Region, Philippines

Abstract

Sentinel species is an important input in understanding environmental health conditions that can provide integrated and relevant information on the possible degree of impact of anthropogenic and natural causes providing information about ecological processes. Identifying "proper set" of ecosystem sentinels will enhance the capacity to monitor and predict environmental change to help guide ecosystem science and conservation efforts.

In the Eastern Bicol Region, we surveyed selected areas to identify the healthy coral reefs to develop a "sentinel integrated system" that will allow regular monitoring of the best reefs and as a showcase for proper coral reef ecosystem management. Please describe the methods briefly. Results showed that there are healthy reefs and indicator organisms were found that are good candidate for a sentinel integrated system that can serve as potential markers of environmental or biological changes. Most healthy reefs are found in Eastern Al (Albay and Lagonoy Gulfs) while those in Asid Gulf and Western Albay have low reef quality. This also corresponds to deep and shallow reef areas respectively.

Keywords: reef management, sentinel ecosystem, indicator species, aquasis.

Introduction

Sentinel species are organisms that are used to detect risks to humans by providing advance early warning systems of natural or human caused environmental change. They are primarily applied in the context of environmental hazards (Van der Schalie, 1999). In this framework, the sentinel system to be developed will allow an understanding of general coral reefs ecosystem so that we will be able to visualize critical snapshots for better protection and management. Opportunities abound for piloting an activity, monitoring, showcasing best practices, comparative research, management, and others Lower and Kendall, 2018, Van der Schalie, 1999).

Worldwide coral reefs are high at risk mostly from anthropogenic activities (WRI 2008) and are declining at a faster rate, losing its valuable goods and services. In the recent study by Rivera-Guieb et al. (2002), it was estimated that almost 20t of fish and other edible marine organisms can be harvested km^{-2} year^{-1} in a good to excellent coral reefs, while a destroyed reef ecosystem can only supply up to 4T km^{-2} year^{-1}.

In the Philippines, Licuanan and Gomez (2000) estimated that less than 5% of the Philippine reefs are in excellent condition (75-100% living corals). This was also corroborated by the statement of WWF (2005) that almost 98% of the reefs in the country are threatened by human activities with 70% at high or very high risk. Almost 20 years later, in the most recent nationwide study by Licuanan et al., (2017) showed that reefs' health condition has worsen and declined noting absence of excellent reefs.

In Bicol Region, reef condition ranges from fair (25-49 %) to good (50-74%) with very minimal sites that have transects with excellent coral cover (Mendoza et al., 2002), with sedimentation and destructive fishing as the main source of reef degradation. In Albay, most of the reefs are in the eastern part of the province, while on the western side, thin strips of reefs fringing on the coastline can be found. Studies conducted in the Region have shown that coral reef conditions are declining (Mendoza et al., 2002). And in the recent study by Mendoza et al., (2021), almost all reef areas in Lagonoy Gulf, eastern Bicol had declined.

However, there are still other reef areas that are well-known as fishing ground by local fishermen in the Region, such as "off-shore reefs" and remote islands and islets which are very rich not only for finfishes but also for highly commercial marine resources such as sea cucumber, bivalves and other invertebrates but are still unexplored. These areas can be good sites both for academic and scientific purposes and as an avenue for eco-tourism. The former is the basis for developing a "sentinel system" that will allow regular monitoring of the best reefs and as a showcase for proper coral reef ecosystem management. It is a unique opportunity to protect our "*last hope*" in the pursuit of a healthy reef ecosystem that can be a showcase and be managed for the next generation. With this project, we are going to identify and map excellent reef ecosystem in Bicol Region for academic/research and eco-tourism purposes and for possible management interventions in these areas.

Developing a sentinel system will enhance and simplify monitoring and evaluation of reef ecosystem functions by basically taking note of species that is indicative of certain environmental and/or biological processes. For example, presence of sea urchins is a positive indication for coral growth as they control algal-coral competition for space, however, too many of them can indicate less predators – which is an indication of overfishing. Another noteworthy example of a sentinel system is by looking at beach front. Fine sand may indicate absence of destructive fishing methods on reef areas, while presence of coral rubbles indicates the opposite.

Main objective of this study is to search for a healthy reef ecosystem in the Region. Specifically, it aimed to search for a potential sentinel reef ecosystem in Bicol Region taking notes of the (1) status of reefs, (2) reef associated organisms and (3) human uses supported by reef ecosystem. And towards the end, the project develop a core group from among the academy/ research agencies closest to the sentinel stations through mentoring cum monitoring and develop a management framework for monitoring and conservation strategies.

Methodology please describe scientifically

Search for healthy reef system

Key Informant Interviews (KII). Around 50 mixed respondents composed of fishers, tourists, divers and researchers per fishing ground were interviewed to determine locations of healthy reefs in the study area. In here, the KI method was done using a semi-structured questionnaire to facilitate gathering of key information to determine indicators such as, fish species, number and quality of reefs including its depth, fishing gears used and other anecdotal information. The questionnaire focused mainly on the knowledge of the respondents on the location, size and other biological and ecological factors of the fishing area and reefs. For the fishers, they were asked of the kind of fish species that were caught in the area and changes of the catch composition if ever.

Use of Maps and other secondary data. The result of KI will be validated through available maps like topographic maps, google maps, and others. For the secondary data, research results and reports that were gathered online and from other offices, were used as basis for the location of the target reef areas.

Assessment and evaluation

Coral reef assessment. In reef areas where reef assessment (scuba diving) is feasible, coral point count (CPCe) method as described by Kohler and Gill (2006) was used to determine percent cover of living coral cover and other benthic lifeforms. This was done by taking images at 1meter interval in a 50meters transect. Images where then analyzed using the CPCe software. Video recordings were done to have a full documentation of the reef system for future and further analysis.

Reef fish assessment. This activity was done in conjunction with the previous method described. Fish visual census technique as described by Hill and Wilkinson (2004) were used to determine reef fish community structure such as biomass and abundance. In here, fishes within the 5m x 25m area were identified, counted and their length estimated.

Development of sentinel monitoring core group in the Region

A core group of faculty-researchers from State Universities and Colleges (SUCs) around the Region were formed that served as "pool of experts" and were in-charged in the monitoring, evaluation and continued education and information among fishing communities in their respective areas. Members of the core group were trained with basic ecological habitat assessments methodologies and their institution have equipment for such undertakings (see fig. 2 for location of the sentinel core group.

Results and discussion

Bicol region is endowed with vast fishing grounds and each has a dominant catch and gear, that basically describes its substrate whether corally, sandy or muddy (Fig 1). Lagonoy and Albay Gulfs are dominated by gill nets and hook and lines type of fisheries, San Miguel Bay is mostly small-scale trawls and entangling nets, while Asid Gulf are dominated by encircling and entangling nets, on the other hand, Ragay Gulf is dominated by mixed modified types of drift gill nets depending on target species. The episodes of fishing regimes in these fishing areas showed the degree of dependence and exploitation in these fishing grounds that have contributed to the overfishing status and habitat destruction (Olaño et al., 2018; Bobiles and Soliman, 2018; Soliman, 2013; Lachica-Aliño et al., 2009; Soliman et al., 2008). While several studies have shown relationship between habitat destruction and decline in fishery production (Armstrong & Falk-Petersen, 2008) and have high contribution to fishery economic losses (Israel, 2004), it is deemed necessary to determine remaining "*potentials*" of the area to serve as a sentinel – to have a unique opportunity to protect the "*last hope*" in the pursuit of a healthy reef ecosystem that can be a showcase and be managed for the next generation.

Five fishing grounds were surveyed based on fishers' interview, maps, reviews, research works and publications. Lagonoy gulf showed the highest number of reefs areas that are usually utilized by fishers in their fishing activities with 39 fishing reefs followed by Asid gulf with 10 reefs then the rest of the Gulfs have 5 reefs each (Table 1). These reefs were also verified from Google Earth map based on the fishers' identification of the location in the map that were shown to them during the interview. The number of reefs is also reflective of number of handline fishers per area (Fish and Boat R database, BFAR RV). It was noted that there were more handline fishers in Lagonoy Gulf as compared to the rest of the fishing areas (Table 1). This can be attributed to the kind and type of substrate in each Gulf, as such, no trawl or any dredging nets are present in Lagonoy and Albay as compared to Asid Gulf and San Miguel Bay, or long and deep entangling and encircling nets which is also abundant in Ragay Gulf (Table 1).

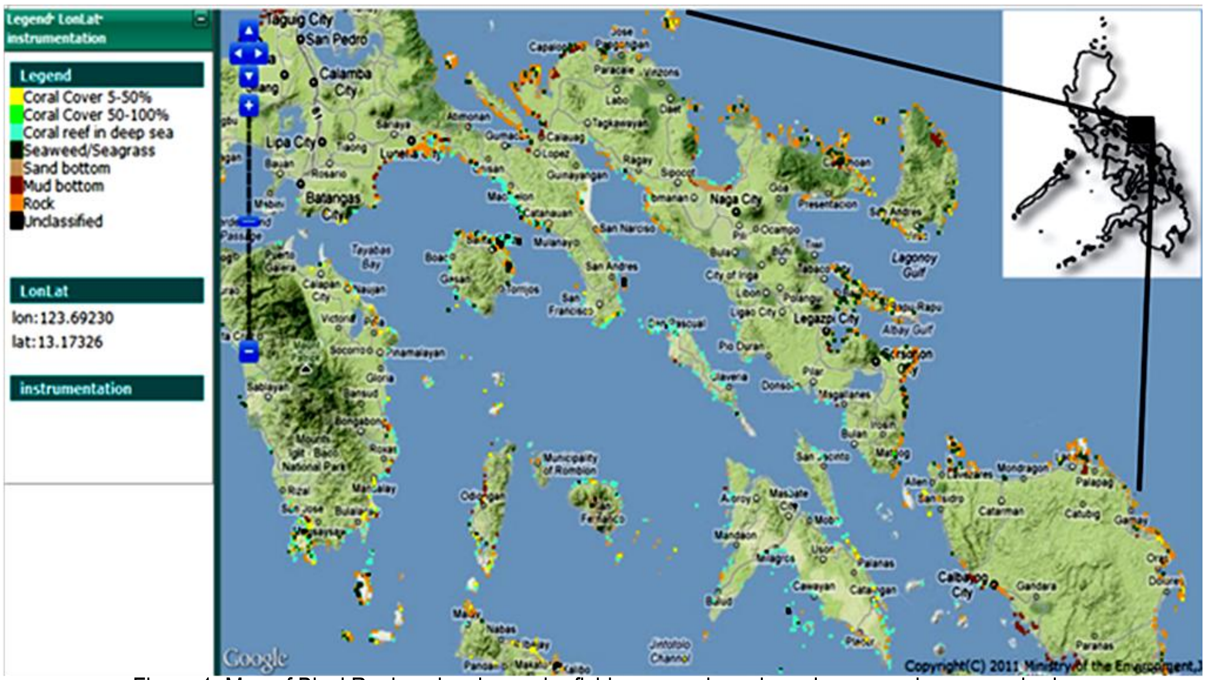

Figure 1. Map of Bicol Region showing major fishing grounds and coral cover and seagrass beds
(image from Ministry of Environment – Japan)

Result of the interviews showed that almost all of the fishers are aware of the locations of deep reefs which they name it based on location relative to the mainland like *bahura sa puro* (reef at end), *bahura kang Bunga* (reef of Bunga) or were called after its depth in fathoms (25, 40, 60 etc.). Interestingly they locate these reefs by triangulation method using prominent landmarks or structures.

Fishers can identify the condition of reefs based on the quantity and quality of reef fishes that were caught. This is mainly based on the indigenous knowledge of the fishers that according to them, good reef areas have "good" quality of fishes – this are the fishes that have high price in the market. In terms of fish caught, most were reef associated fishes which are dominated by reef carnivores which are high valued such as groupers, trevallies and snappers. Also, evident catch were the reef herbivores such as rabbitfishes, surgeonfishes and parrotfishes which are important determinants in coral-algal competition.

Table 1. number of deep (fishing) reefs identified in five fishing grounds in Bicol.

Fishing ground	No. of deep reefs identified	Average depth (fathoms)	Average area (has.)	Dominant fishing gear	Type of fish caught	Quality of reef*
Lagonoy Gulf	39	30	3	hook and line; gill nets	pelagics and reef ass. fishes	good
Albay Gulf	18	22	2.5	hook and line; gill nets	pelagics and reef ass. fishes	good
Ragay Gulf	20	20	1.5	drift gill nets	small pelagics	fair
San Miguel Bay	8	10	< 1	trawls; entangling nets	Demersals; crustaceans	fair
Asid Gulf	10	10	< 1	encircling and entangling nets	Demersals; crustaceans	fair

***** as perceived by fishers based on their indigenous knowledge on the relationship between the type of fishes (catch composition) and the quality of reef. While others have basic knowledge because they have dived while fishing - (fair – 25 - 50% live coral cover; good – 50 - 75% live coral cover).

Several studies on reef assessments were also utilized to describe the status of the reefs in various fishing grounds in Bicol. It showed that reefs in Bicol Region are generally in fair condition - mostly in range between 25% to 50% living coral cover (LCC) and few in poor condition that is less than 25% LCC (Table 2) (Cabiles et al., 2017; Mendoza et al., 2017; Mendoza et al., 2002; Mendoza et al., 2000). And trend shows a declining coral cover (Mendoza e al., 2021), which is almost similar to the national assessment results (Licuanan et al., 2017). This alarming situation could be an indication for the urgent establishment of a sentinel system for reef ecosystem in the Region for conservation and improvement. This is crucial as studies showed that MPAs are not well efficient in improving reef condition (Mendoza *et al*., 2021; Maypa *et al*., 2012). Interestingly, it showed that deep coral areas appeared to have higher living coral cover as compared to shallow reef areas (Mendoza et al., 2021). However, in one site in Asid Gulf that is neither a protected area nor deep reef area, living coral cover is the excellent condition (75-100%), and it showed that it is controlled by a patriarchal family clan that prohibits fishing and entry in the area, which underpins importance of strict implementation. While the declining reef condition in Bicol is linked to high exploitation and destructive fishing activities in the past, low or lack of implementation of fisheries related rules and regulations have contributed to its deterioration which was also corroborated in surveys from among the fishermen and the coastal communities.

With the present state of coral reefs alongside the diminishing fishery production, protecting the remaining resources is supposed to be critical to prevent its continuous decline. And establishing an integrated sentinel system can enhance and simplify monitoring and evaluation of reef ecosystem functions by basically taking note of species that is indicative of certain environmental and/or biological processes.

Several species can be used as indicators to guide managers and planners in the protection and conservation of reef resources. These species can serve as potential indicators of ecological integrity. In most cases, macroinvertebrate and fishes are used to represent reef's health (Green et al., 2009; Gerhardt, 2002; Hourigan, et al.,1988). Noticeable were the sea urchins which are used as a positive and/or negative indicator of reef's ecosystem. These organisms are considered positive indicators in the sense that they control coral-algal competition but are considered negative indicators of overfishing. Abundance of sea urchin in the reef would indicate less predators which may induce bioerosion (McClanahan, 1992; McClanahan, 1995). On the other hand, crown of thorns (COT) which are coral polyp predators were observed to be minimal, except in areas where regular COT collection as part of clean up drive are usually done.

Table 2. Living coral cover in selected fishing grounds in Bicol.

Fishing ground	Range of live coral cover
Lagonoy Gulf	10 - 48% [a, c]
Albay Gulf	18 - 56%[b, c]
Ragay Gulf	21 - 36% [b, c]
San Miguel Bay	15 - 33% [c, d]
Asid Gulf	16 - 66% [c, e]

a - Coral resiliency project (2020); b - SCREMP Project (2015), c - this (Aquasis) Project (2018); d - BIODIVE Project (2002); e - Scallops Project (2015)

Another good indicator that can be used to describe reefs' health is the density of juvenile corals (<5cm in diameter). The abundance of coral recruits can explain in the capacity of the reef area for fast recovery during a catastrophe. Observation showed that juvenile corals are abundant in areas sea urchin and herbivore fishes are abundant. Presences of these herbivores facilitate coral larval settlement (Nozawa et al., 2020).

In terms of developing an ecosystem sentinel, Bicol reefs are showing good indication for its establishment. Occurrences of deep reef areas with good coral cover is excellent for an integrated aquatic sentinel. Additionally, abundance of indicator species as listed and briefly explained in Table 3, can further increase probability of successful establishment of a sentinel system in the Region.

Although, recent study of Mendoza et al., (2021) showed the presence of more negative indicators like algae, crown of thorns, abundance of sea urchins and few and smaller parrot fishes. This may not ecologically sound good, but with the presence of other more essential elements of an ecological sentinel, not to mention strong support from LGUs, NGAs and NGOs in the Region, there is a strong possibility that development of an integrated aquatic sentinel system (AQUASIS) is feasible.

Table 3. List of indicator species that can be used in the reef sentinel system in Bicol Region.

INDICATOR SPECIES	REMARKS	INDICATION
Butterfly fish	Positive	Indicator of good coral cover (Hourigan et al., 1988)
Parrotfish and other herbivore	Positive	Remove algae, sediment and other material by closely cropping or scraping the reef surface, leaving

fishes		shallow scrape marks on the reef substratum (Green et al., 2009)
Snappers, grunts and groupers	Positive	The abundance of key carnivore fish species (snappers, grunts and groupers) is important for healthy reefs in terms of predator control and preventing the occurrence of trophic cascades. Furthermore, the abundance of key carnivore fish gives insight on the effect of fishing since they are commercially important species (Hawkins & Roberts, 2004)
Abundance and richness of fish species	Positive	The abundance and richness of fish species is influenced by coral cover and habitat complexity. The percentage of cover and richness in coral species are strongly associated with fish species richness and abundance (Komyakova et al., 2013).
Triton Shell	Positive	Indicators of anthropogenic threats as trends in their abundance reflect intensity of harvesting. one of the few predators of *A. planci* and extremely important for keeping this species in check. *C. tritonis* is a much sought-after shell within the curio trade for its aesthetic affects and its high economic value has led to its exploitation over many years (Birkeland, 2015).
Juvenile Coral	Positive	Juvenile coral density is a better measure of health according to Edinger, et al., (2000).
Giant clams	Positive	Indicators of anthropogenic threats as trends in their abundance reflect intensity of harvesting. are important filter feeders, converting large quantities of organic matter into protein). The *T. gigas* are found in increased abundance and size within marine protected areas, indicating the best management practice for sustaining populations (Hopkins, 2009)
Sea cucumbers	Positive	Sea cucumbers are important for healthy reefs, because of their significant role on coral reefs in nutrient recycling by converting organic detritus (Purcell et al., 2013).
Crown of thorns	Negative	Indicator of disturbance due to its proliferation at larval stages in the presence of increased nutrient runoff from agricultural practices (Brodie et al., 2005)
Sea Cucumbers	Negative	Indicators of anthropogenic threats as trends in their abundance reflect intensity of harvesting. Holothurians are susceptible to overexploitation due to their late maturity, density-dependent reproduction, and low rates of recruitment. they are macro detritivores and consume organic detritus (Purcell et al., 2013).
Sea Urchin	Positive and Negative	Controls coral-algal competition (Idjadi et al., 2010). But presence of increased numbers these echinoids indicates over fishing and harvesting reducing predator populations. Under low to intermediate predation levels sea urchin populations can reach or be close to the carrying capacity of their algal food resources and they can strongly affect coral reef structure through bio erosion has always been a major force in determining the shape and form of reefs it

		can cause coral degradation if echinoid densities are too high (McClanahan, 1992; McClanahan, 1995).
Drupella Snail	Negative	Drupella snails seem to be good bioindicators for areas with regular fishing and invertebrate harvesting. They exhibit positive RDA correlations with invertebrate harvest for food and curios and hook/line/net fishing. However, over-fishing could increase Drupella populations by removing predators (Grimsditch, 2004)
Algae	Negative	Fleshy algae were chosen as an indicator of nutrient enrichment associated with sewage pollution. (Bruun 2012)
Sponges	Negative	On some reefs, a high abundance of encrusting sponges may indicate high nutrient levels or other problems (Wilkinson, 1987)
High density of macroalgae	Negative	High macroalgae cover is an indicator of poor reef health because of its negative effect on corals. Firstly, macroalgae take up the space that coral recruits would settle on. Secondly, macroalgae are able to overgrow coral recruits and small corals of a few years old. And lastly, macroalgae can also partially overgrow larger corals, inflicting damage to the corals and causing the larger corals to separate into smaller patches (Hughes et al., 1999).
Low coral Cover	Negative	Lower coral cover in turn leads to reduced reproduction of coral polyps, because of a lower production of gametes and furthermore because the rate of fertilization of those gametes is reduced since distances between coral colonies increase. This can also result in an increase of budding, leading to a less genetically diverse reef and thus a less stable reef (Knowlton, 2001).

To ensure the continuity and sustainability of sentinel implementation in the Region, we developed a network of researchers providing as “pool of experts” that will be in charged in the monitoring and evaluation of the sentinel integrated system in their areas of responsibilities. Young faculties of the five state universities and colleges in Bicol were trained through collaboration with several ongoing research and extension activities of Bicol University such as the IDIG program of BU-CHED-Higher Education Regional Research Center (BU CHED-HERRC) and DOST funded projects, they were trained on coral reef survey and reef restoration methodologies. In some cases, we collaborate with them in some research projects and employs partnership through *mentoring cum monitoring* scheme.

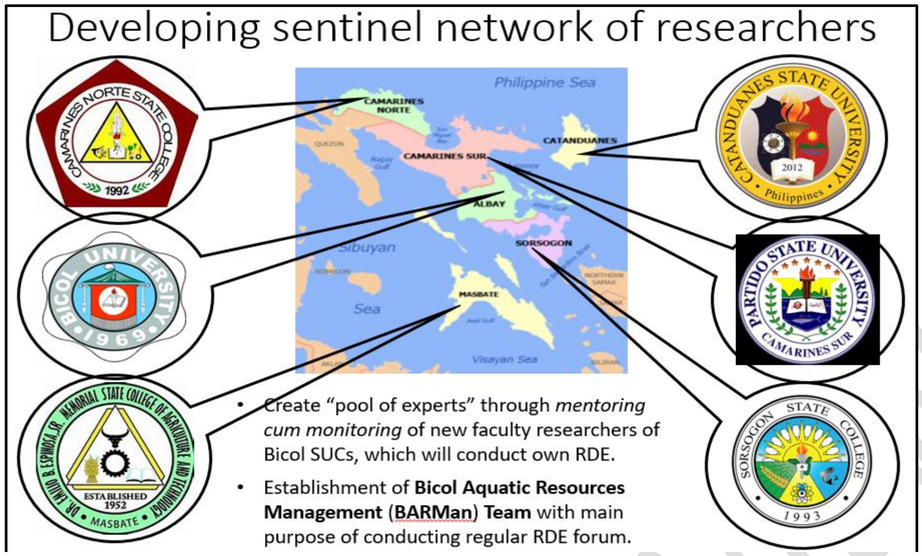

Figure 2. Establishment of network of researchers that will conduct monitoring of sentinel ecosystem in their respective area.

How sentinel system works?

Around the world several sentinel programs have been implemented to serve as an early warning or diagnostic indicators of environmental changes that can have severe impact to humans such as pollutions, environmental integrity and biodiversity (Gerhardt 2002). In this study however, sentinel species will be utilized to serve as bioindicators or ecological signals of environmental changes and due to their predictive characteristics, such as biomass or abundance, their threshold capacities for responding to changes in the environment can easily be recognized as compared to other ecosystem components, or when they are exposed to changes earlier than other ecosystem components (see table 4 from Long Island Sound Sentinel Program). Understanding and awareness of these sentinels can provide recognizable relationship between physical processes and biological responses, and can be used to monitor processes that are difficult to observe directly (Hazen et al., 2019). Observing ecosystem sentinels can lead and enhance ecosystem science and conservation efforts. Relevant data from ecosystem sentinels can be incorporated to provide appropriate management approaches such as adaptive, ecosystem-based, or co-management strategies to help support fisheries adaptation in new and changing environment.

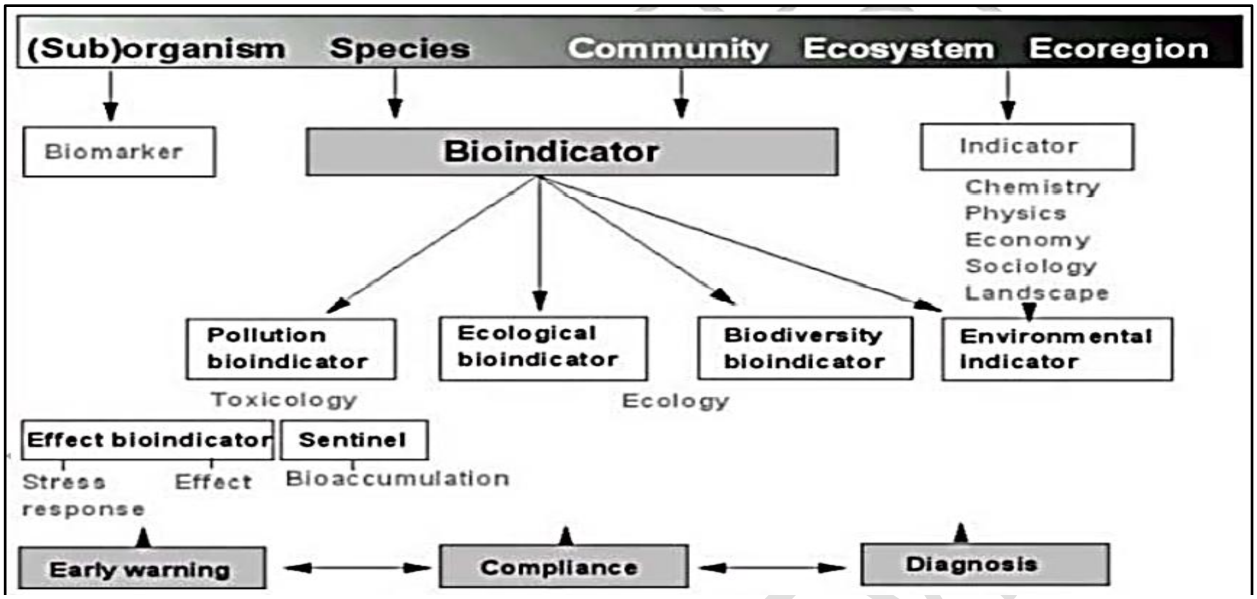

Figure 3. Types of bioindicators in the context of their use in biomonitoring (from Gerhardt 2002).

This can be seen in the developed *aquasis* framework in table 5. Since each fishing ground possess unique reef ecosystem features, determining possible sentinel candidate/s for M&E is important. After they are identified, M&E protocol will be established. In the M&E implementation, faculty researchers from different SUCs in Bicol will have vital role in the conduct of monitoring and can be in partnership with LGUs through methodology trainings of the personnel or through *monitoring cum mentoring* approach. Feedback mechanism is in place to update management options to improve conservation and sustainability procedure.

Table 4. List of approved sentinels and associated indicators that are or can be measured in an attempt to detect change brought about by climate change. (Adopted from Long Island Sound Resource Center Ref?

Fisheries of Long Island Sound and Associated River Systems	
Sentinel	Index
Lobster	• Lobster larval abundance from fisheries independent monitoring; Catch per unit effort • Indices from fishery monitoring • Neoparamoeba distribution in water column; • Temperature effects – analysis of catch distribution in LIS Trawl Survey and LIS commercial catch. Assay to measure heat shock protein
All shellfish (clams, mussels, oysters, scallops)	• pH • Alkalinity • CO2 concentrations

Eastern Oysters (shellfish): changes in populations due to Dermo or MSX; ocean acidification, potentially invasive species that are predatory or compete for resources	• Dermo and Haplosporidium which causes MSX • pH changes effects on calcification
Northern quahog (shellfish): changes in populations are due to disease (QPX), ocean acidification, potentially invasive species that are predatory or compete for resources	• % Infected clams/area (disease prevalence & intensity) • Range changes in parasites
Bay scallops (shellfish): Changes in populations due to habitat loss (eelgrass): ocean acidification,	• Distribution and abundance of shellfish and habitat (eelgrass)
Is there a change in finfish pathogen abundance and occurrence?	• Proportion of population infected with the pathogen or annual index of mortalities directly attributable to this disease (difficult) • Parasite prevalence, abundance, seasonality, location, pathology: including but not limited to: *Lironeca*, Lernanthropus, *Lernaeenichus*
Diadromous fish	• Trend analyses (similarity coefficient /regression) of survey catch data; correlation of adaptation group abundance and individual species, with LIS temperature data • NY would only see changes to timing, more applicable in CT

Table 5. Process flow of the AQUASIS framework for monitoring and conservation strategies Ref?

STEP	PROCESS	REMARKS
1	List of sentinel species for monitoring and evaluation	Survey on the possible sentinel candidate in each fishing ground or ecosystem
2	Database (baseline)	Repository of data – baselines and other reports
3	Development of monitoring protocol	Determination of monitoring/survey methodologies.
4	Monitoring and Evaluation	Regular M&E Report writing & sharing - publication Capacity building for LGUs
5	Changes (+ or –)	Determination for changes whether + or -. Review of related studies
6	Determination of contributory factor/s for the change	Identification of causal factors for the change/s. Review of related studies
7	Management option	Development of management strategy to mitigate possible impact/s.

Overall, development and/or establishment of a reef sentinel in Bicol is feasible. Available data suggests that establishment of such should be done the soonest possible time due to the sustenance fisheries is dependent on these ecosystem – showing pressure on these reefs.
Increasing negative reef health indicators signals likelihood of reef degradation. And it is recommended that establishment of aquatic sentinel system in areas with good coral condition should be done. Furthermore, regular monitoring coral reef systems should be implemented, so that science-based management decisions can be made to mitigate the threats to these fragile ecosystems. A sustainable harvesting of good reef indicators alongside with conducting habitats restoration and reducing sources of pollution should be implemented and lastly, awareness promotion in schools and coastal barangays and utilize social media platform.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist.

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