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Ichthyological Indication of Aquatic Ecosystems: Coral Reefs

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Abstract—Principles of the biological indication of water ecosystems on the basis of fish community analysis are considered. A comparative study of fish community structure and the condition of a coral reef in Vietnam (Nhatrang Bay) was conducted. The study revealed a clear association between the ecological integrity of corals and the richness of the reef ichthyofauna. Perspectives of the approach based on fish community analysis for biological indication of various water bodies are discussed.

Scientific research in the area of biological indication is extremely important. Unlike instrumental control of physical and chemical parameters of the environment, bioindication is based on direct assessment of the condition of biological objects and thus reflects the actual status of the respective component of the ecosystem. It allows rapid assessment of the resulting net effect of external factors on the ecosystem and facilitates further routine monitoring.

The methodology of biological indication is primarily based on separate indicator organisms (*Marine Organisms*…, 1988). Measures of their abundance, distribution, and morphofunctional condition provide the ecological characteristic of the studied natural complex and represent the basis for its appropriate management. Nonetheless, the cenotic taxation of ecosystems, traditional in field zoology and botany, is rather uncommon in the area of biological indication. This is especially true for aquatic ecology, the biological indication of water ecosystems, which is still mainly based on separate indicator organisms. Therefore, the efforts of investigators are primarily concentrated on the search for various indicator species and their practical use (*Marine Organisms*…, 1988). At the same time, the cenotic approach, based on the analysis of representativeness of organisms of various taxonomic groups and the condition of main components of the biotope, seems the most productive for the assessment of such

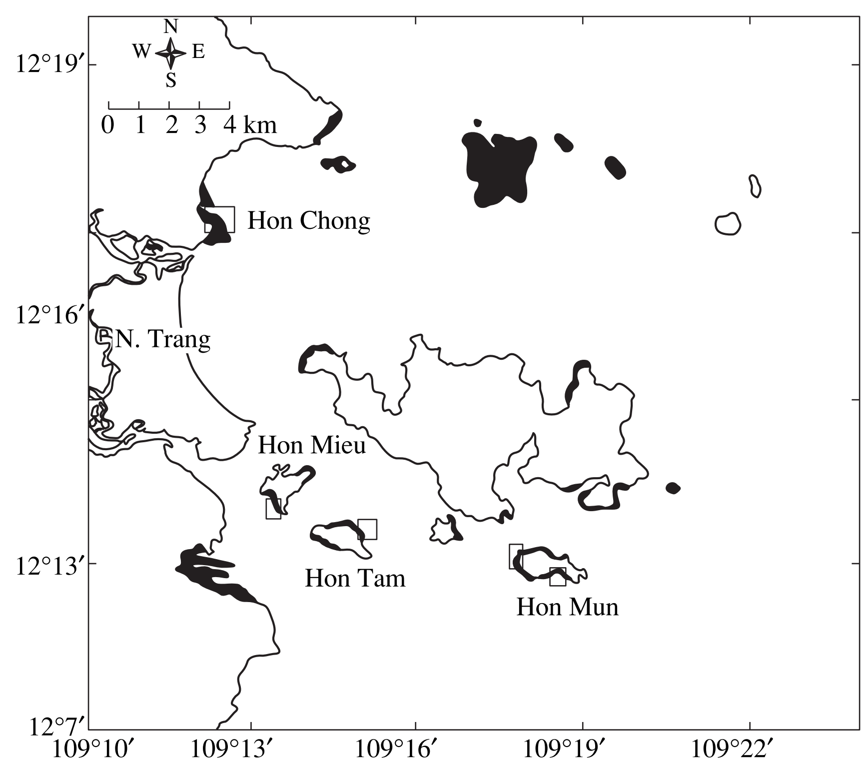

Fig. 1. The map of the study area. Coral reefs are designated by black areas, stations of data collection, by squares.

Table 1. The list of fishes, recorded in coral reefs of the Nhatrang Bay

Taxonomic position	
Gasterosteiformes	Labridae
Serranidae	*Thalassoma hardwikii*
Lutjanidae	*Th. lunare*
Mullidae	*Gomphosus varius*
Chaetodontidae	*Labroides dimidiatus*
Chaetodon vagabundis	*Bodiatus axillaris*
Ch. auriga	*B. mesothorax*
Ch. trifasciatus	*Coris variegata*
Ch. trifascialis	*Coris* sp.
Ch. ocellicandis	*Halichoeres richmondi*
Ch. speculum	*Halichoeres* sp. 1
Ch. ulietensis	*Halichoeres* sp. 2
Ch. acuminatus	*Halichoeres* sp. 3
Chaetodon sp. 1	Scaridae
Chaetodon sp. 2	*Scarus schlegeli (?)*
Pomacentridae	*Scarus* sp. 1
Abudefduf septifasciatum	*Scarus* sp. 2
Dascyllus trimaculatus	*Scarus* sp. 3
D. reticulatus	*Scarus* sp. 4
Chromis amboinensis	Acanthuridae
Ch. cyanea	*Acanthurus auranticavus*
Ch. weberi	*Ac. pyroferus*
Ch. atripectoralis	*Acanthurus* sp. 1
Pomacentrus moluccensis	*Acanthurus* sp. 2
P. chrysurus	*Acanthurus* sp. 3
P. leucozonus	*Ac. nigrofuscus*
P. vaiuli	*Zebrasoma scopas*
P. lepidogenys	*Ctenochaetus binotatus*
Eupomacentrus sp. 1	Tetradontidae
Eupomacentrus sp. 2	*Tetradon* sp. 1
Plectroglyphynodon dickii	*Canthigaster valentini*
Hemiglyphynodon plagiometopon	Balistidae
Neoglyphynodon nigroris	*Rhinecanthus aculeatus*
N. melas	sp. 1
Cheiloprion labiatus	Diodontidae
Ch. unimaculatus	sp. 1
Amphiprion sp.	Herriidae
	Herris sp. 1
	Pomadaciydae
	sp. 1
	sp. 2

complex and multicomponent water ecosystems as lakes, estuaries, and marine shelves. In this context, we note the assessment of the quality of northern lakes, based on an analysis of the fish portion of their community (Reshetnikov *et al.*, 1982).

The aim of this work was the further development of cenotic principles of bioindication of water ecosystems, in this case applied to coral reefs. The major task of the study was to obtain data on fish community composition and develop an approach to their quantitative analysis within the context of the cenotic principles of bioindication of water ecosystems.

According to the current views on the system organization of natural complexes, the fish part of the community represents an extremely important component of the coral reef ecosystem. Therefore, assessment of the coral reef community is a necessary element of its systematic analysis and an important ecological indicator. However, we believe that the fish portion of the community should be considered only as a single partial index. Obviously, the quality of the aquatic environment reflects a whole complex of cenotic characteristics of water organisms of various taxonomic groups, such as corals, zoobenthos, macrophytes, etc.

MATERIALS AND METHODS

The study was conducted in coral reefs of the Nhatrang Bay, South Chinese Sea, from February to March 2000. The coral reef communities of this bay, earlier very large and with abundant marine life, are currently significantly degraded, and the community of invertebrates and fish is poor. Coral reefs are almost destroyed near the continental shore, but are in a better condition in near-island regions. Therefore, our study was conducted in islands (Hon Mun, Hon Mieu, and Hon Tam). Coral reefs at the continental shore (Hon Chong) were analyzed for comparison.

In each station, we conducted censuses of dominant fish groups and main coral life forms. We believe that such overall characteristics of hydrobionts of various taxonomic groups are the most reasonable for cenotic biological indication. For the analysis of fish community and coral cover, we used underwater visual censuses by divers (*Survey Manual*…, 1994). The belt transect—a measuring type with a length of 30 m—was placed on the bottom. In total, 17 transects were installed in various stations. The depth in study locations did not exceed 8–10 m. After the transect line was set up to the beginning of the census, it usually took 2–3 min. Then, the observer in skin-diving equipment slowly moved along the transect line and counted the fish within the 2-m area on both sides of the transect. The results of the census—the taxonomic position of fish and the number of individuals—was immediately recorded on a plastic plate underwater. To facilitate identification of fish in the field, we made a special waterproof identification key with photographs of

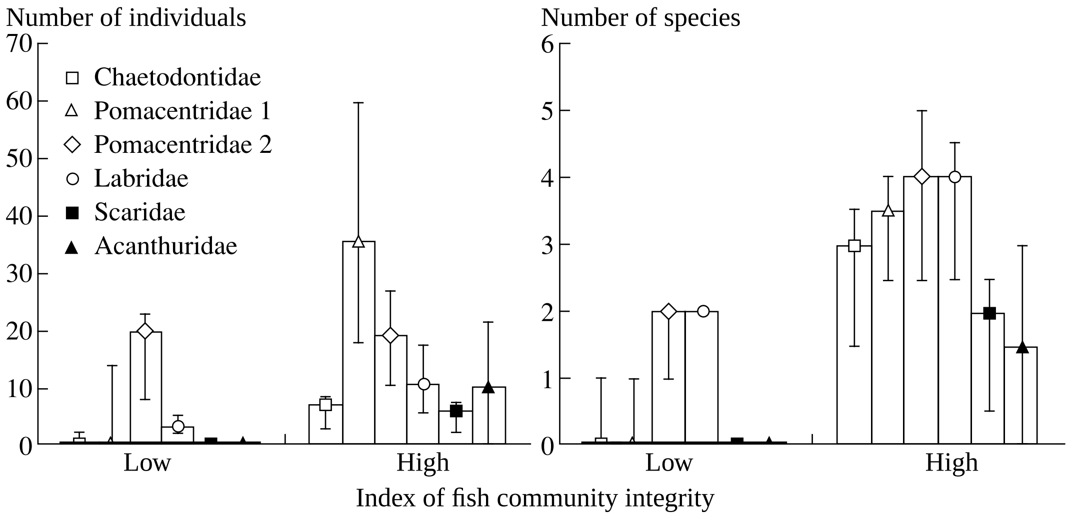

Fig. 2. The composition of degraded and relatively intact coral reef fish communities in the Nhatrang Bay. Fish groups: Chaetodontidae (1), Pomacentridae 1 (2), Pomacentridae 2 (3), Labridae (4), Scaridae (5), and Acanthuridae (6).

fishes inhabiting the Nhatrang Bay. This key was prepared on the basis of the *Checklist of Fishes of the Nhatrang Bay* (unpublished) and numerous photographs from various sources, kindly provided by Truong Shi Ki (Nhatrang Institute of Oceanography). Seventy-six fish species were recorded during the censuses. Immediately after the fish census, we conducted an analysis of coral cover using the line and point intersect transect method. (*Survey Manual*…, 1994). The data were also recorded underwater onto a plastic plate.

RESULTS

The results of the censuses are presented in Table 1. Based on these results, the following dominant fish families were distinguished: Chaetodontidae, Pomacentridae, Labridae, Scaridae, and Acanthuridae. These families include the most common diurnal fish species inhabiting the Nhatrang Bay. These fish, in addition, are easily identifiable underwater by their body shape and coloration. The most massive family, Pomacentridae, was additionally split into two groups: (1) schooling fish dwelling in midwater *Abudefduf* and *Dascyllus*, and (2) solitary bottom-dwellers *Pomacentrus*, *Eupomacentrus*, *Hemiglyphonodon*, *Neoglyphonodon*, and *Amphiprion.*

The data on fish community composition represented the basis for its further analysis in various locations of Nhatrang Bay. The most abundant and species-rich were coral reefs in the nearshore coral reef habitats of Hon Mun. The fish communities of other islands, Hon Tam, and Hon Mieu, were poorer in the taxonomic sense, less abundant, and were characterized by a dominance of bottom-dwelling Pomacentridae (group 2).

To obtain an overall measure of fish community integrity applicable in various parts of Nhatrang Bay, we used nonmetric multidimensional scaling (Stevens, 1996). The resulting index of fish community integrity includes qualitative and quantitative measures of the community composition, reflecting its overall specificity and integrity. Such approaches, based on multivariate analysis, are becoming more popular for analysis of general patterns of stress on multispecies assemblages (Warwick and Clarke, 1995). The index of fish community structure significantly correlates with traditional cenotic indices calculated for various study locations in Nhatrang Bay (Table 2). However, unlike traditional indices, the multivariate approach takes into account and is based on numerous relationships between different measures. The values of the fish community integrity index allowed us to rank the local fish communities in Nhatrang Bay (Fig. 2). The left histograms in Fig. 2 characterize the ichthyocenosis of degraded coral reefs at the continental shore, whereas the right histograms describe the fish community in relatively less degraded Hon Mun.

To analyze the relationships between the coral cover and the fish community integrity, we conducted a cor-

Table 2. Correlations between the fish community integrity index and other cenotic measures

Index	R_S	t_{15}	p
Simpson dominance index, individuals	–0.46	–2.02	0.061
Simpson dominance index, species	–0.62	–3.08	0.008
Margalef species diversity index D_1	0.95	11.60	0.000
Margalef species diversity index D_2	0.89	7.75	0.000

Table 3. Correlations between the coral reef fish community integrity index and coral cover measures

Characteristic of the bottom substrate	R_S	t_{15}	p
Sand	–0.20	–0.77	0.450
Rubble, unconsolidated coral fragments	–0.40	–1.68	0.113
Total percentage of live coral cover	**0.47**	**2.04**	**0.059**
Dead coral colonies	–0.12	–0.46	0.654
Branching corals	**0.62**	**3.05**	**0.008**
Coral foliose	–0.12	–0.49	0.633
Coral tabulate	–0.09	–0.34	0.741
Submassive corals	0.34	1.40	0.182
Massive corals	0.04	0.15	0.885
Coral encrusting	**–0.51**	**–2.33**	0.034
Soft corals	0.39	1.66	0.117
Coralline algae	0.05	0.18	0.863
Other	0.20	0.81	0.432

relation analysis, which is presented in Table 3. The correlation between the fish community integrity and the percentage of live coral cover turned out to be relatively low, though significant. Other coral measures also correlated relatively weakly with the integrity index.

DISCUSSION

The results of this work provide the basis for an ichthyological approach for biological indication of aquatic ecosystems. The practice of fish studies, based on underwater observations, substantiated the development of cenotic research in ichthyology. The role of ethological studies of coral reef fishes is especially significant (Randall, 1963; Risk, 1972; Helfman, 1978; Sale, 1980; Mochek, 1987; and others).

The patterns revealed during fish studies provided the basis for the current views on a unitary system of ecological and ethological interactions within the community of coral reef fishes. Theoretical positions, developed on this basis, suggest that alterations of the biotope components or fish community composition can provide a reliable biological indicator of disturbances of the aquatic ecosystem. It should be emphasized that in this case we stress the cenotic approach, i.e., assessment of the whole fish community, rather than use of particular single fish species. In our opinion, the use of one or few indicator species is far from universal and, in some cases, may be misleading.

For example, the well-known approach to biological indication of coral reefs based on species diversity and behavior of corallivorous butterflyfishes (Chaetodontidae) (Crosby and Reese, 1996) is completely inapplicable to the Nhatrang Bay. In this place, butterflyfishes are subject to intense commercial fishery for aquarium purposes. Therefore, their abundance is reduced, and their behavior in the presence of divers is significantly different (the butterflyfish are apparently afraid of divers). However, other fishes are less affected by such anthropogenic pressures: small fish in coral stations are numerous and are not so afraid of divers. Therefore, in this case it is impossible to base analyses only on butterflyfishes, and the most appropriate approach to bioindication should ideally involve a complex assessment of the whole fish community. Thus, not only the partial goals of biological indications are solved, but the condition of the whole ichthyocenosis is assessed.

The results of our study indicate that it is impossible to use only a single component (e.g. corals) of the whole ecosystem for its assessment. Such an approach currently predominates. However, according to our data, there is no strong correlation between the condition of the coral cover and the integrity of the fish community. Many other studies (e.g. Roberts and Ormond, 1987; Roberts *et al.*, 1988) also documented such a pattern. Thus, only a complex cenotic assessment of the most important components of the coral reef ecosystem may provide a reliable indicator of the whole ecosystem condition.

We suggest that the methodological viewpoints developed in this study are not limited to coral reefs and can be used in other water bodies.

CONCLUSION

This study substantiated the appropriateness of the cenotic approach to biological indication of the coral reef ecosystem. Analysis of the coral reef fish community is based on a key component of the ecosystem and reflects, within certain limits, the level of integrity or degradation of this natural complex. However, assessment of only one component of the biota is not enough for adequate evaluation of the current status of the whole ecosystem. Our data suggest that the fish community integrity does not depend much on the condition of the coral cover.

In our opinion, a system-based assessment of the coral reef is needed, which should be based on a complex assessment of hydrobiological cenoses of various taxonomic groups (fishes, corals, benthos), rather than on the use of a few indicator species.

We suggest that the principles of cenotic biological indication developed in this work can be especially appropriate for the assessment of environmental quality in coral reefs and other aquatic hydrobiological complexes.

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