Bull. Fac. Fish., Mie Univ.
No. 8 : 31—48
October 1, 1981

Studies on the Artificial Fish-reefs in Kata Bay, Encrusting Organisms and Fish Community

Kunihiko IZAWA and Kazuharu KURIFUJI*
Faculty of Fisheries, Mie University

In the light of the present situation that placement of artificial fish-reefs has been strongly promoted in order to develop inshore fisheries, we began to study three multi-component artificial fish-reefs in Kata Bay, Pacific coast of Central Japan, as a model of artificial fish-reefs, to clarify function and effect of them. As a fundamental study, in this article we made a general description of the study fish-reefs first, then dealt with encrusting organisms and fish communities.

The study fish-reefs were built in 23–35m depth, from 1973 to 1976, almost at the middle between two set-nets situated close to each other. Main aim of placement of the fish-reefs is to attract fish for the set-nets. Three multi-component artificial fish-reefs are each constructed of 785m^3 of quarry rocks, 124 concrete shelters, and 259 units of tier shelters. The tier fish-reef is accompanied by some five wooden ships.

Biological surveys were carried out six times from 1977, eleven months after completion of the fish-reefs, to 1980, through direct observations by using SCUBA. Besides automatic under-water cameras acting by interval-timer and under-water TV with remote-control were occasionally used to watch come-and-go of fish on the fish-reefs.

Communities of encrusting organisms are referable to a feather duster worms-moss animals complex. Most dominant species are *Hydroides norvegica* and *Caberea lata*. Flora is very scarce as it is too deep. Though restricted to the most shallow, quarry rock fish-reef, only a brown alga, *Ecklomiopsis radicola*, has been found flourishing. 81 fish species representing 41 families and 64 genera were observed in all. Most frequently seen and important commercial fish are sardine, *Sardinops melanosticta*, anchovy, *Engraulis japonicus*, beackperch, *Oplegnathus fasiatus*, grunt, *Parapristipoma trilineatum*, and jack mackerel, *Trachurus japonicus*. Fish observed on the fish-reefs were classified on the basis of mode of life and relationship to the fish-reef into three categories under the names of visitor, transient and resident. Some discussions on the relationships between fishes belonging to respective categories and the fish-reef were made and ended with a conclusion that the height of the artificial fish-reef is one of the important factors yeilding sufficient reef-effects.

Keywords: arificial fish-seef, fish community

* Fisheries, Commerce & Industry Section, Owase City

Fishermen have known for centuries that concentrations of fishes are usually found around not only offshore banks and rocky reefs but also sunken objects like a wrecked ship. Placement of artificial fish-reefs was adopted as an object of the State subsidy in a link of the inshore fisheries ground improvement scheme in 1954 and it has every since been promoted by the State and local self-governing bodies. In the last decade this scheme has actively been carried out, and by this time numbers of, and various scales of, artificial fish-reefs have been placed in almost all of the coastal waters around our country.

Since 1976, we have studied function and effect of artificial fish-reefs in the Sea of Kumano. The three multi-component artificial fish-reefs dealt with here were placed in Kata Bay from 1973 to 1976, between two set-nets located close to each other. The main aim of placement of these fish-reefs is to attract fish for the set-nets.

We have grappled with studies of these fish-reefs from two directions. One is of the artificial fish-reefs themselves including biotic communities developed on or around them. The other is an estimation of reef-effects, for the set-nets in question, through analytical research of fish catches. In this article, general descriptions of the study fish-reefs are made first, and then, encrusting organisms developed on the surface of the fish-reefs and fish communities observed around them are dealt with, which are matters referred to the former.

Scale of Surveys and Methods

In order to clarify shapes of the study fish-reefs and the arrangement of them in the water the first survey was made in October 1976, just after placement of them was finished. Biological surveys were begun in September 1977, eleven months after the placement, and were subsequently carried out in October 1977, in May, October and December 1978, in August 1979, and in July 1980. Two or three days were set for each survey. Diving observations by using SCUBA were made at least more than once at every fish-reef in each survey. The diving time that we could spend for actual observation on the sea bottom, was 15–30 minutes. In addition to the routine of direct observations, automatic under-water cameras acting with interval-timer and under-water TV with remote-control were used occasionally to observe behavior of fish on the fish-reefs and to watch their come-and-go.

General description of artificial fish-reefs

Three artificial fish-reefs studied here are each composed of different kinds of materials, e.g. quarry rocks, concrete shelters and discarded tier shelters. They are placed far back in Kata Bay at about the middle between two set-nets located close to each other, and arranged almost straight toward the offing; the quarry rock fish-reef is placed at 23m in depth; the concrete shelter fish-reef at a distance of about 75m

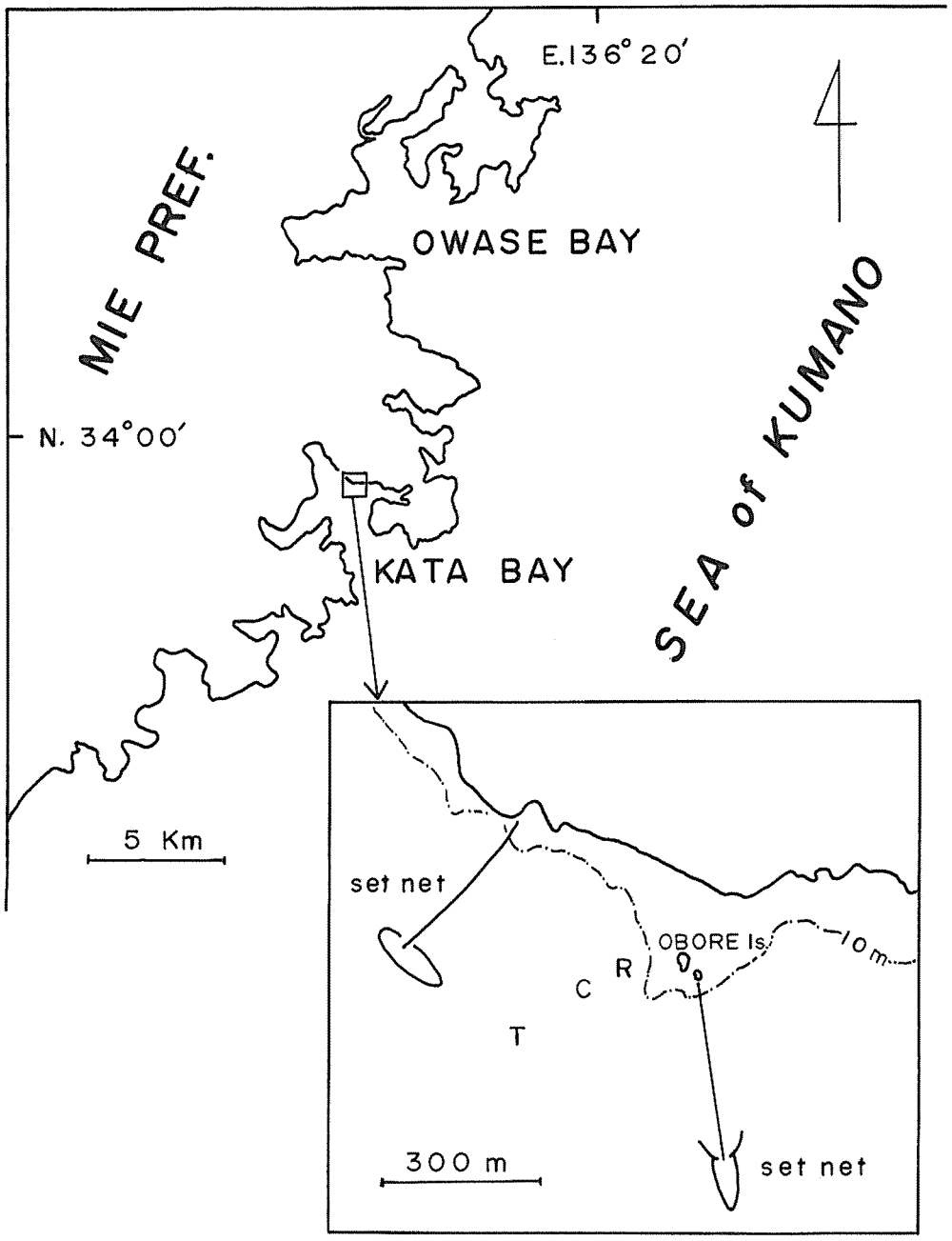

Fig. 1. Locality map of Kata Bay, showing the location of the three artificial fish-reefs. Abbreviations: R, quarry rock fish-reef; C, concrete fish-reef; T, tier fish-reef.

from the former, at 26m depth; the tier shelter fish-reef about 150m apart again from the last, 35m depth, (Fig. 1). Though only a part of the quarry rock fish-reef touches the edge of the natural rocky reef in the water which extends from a rockhead, Obore Island, the other areas surrounding these fish-reefs are a smooth sandy bottom gradually deepening offshore.

Sediments

Grain size analyses of bottom sediment is made on core samples gathered from nearby fish-reefs by using a can 115mm long with a diameter of 100mm.

The results are summerized in Fig. 2 and Table 1.

Temperature

Water temperature around the fish-reefs ranges from 14°C in winter to 23°C in summer at the bottom and from 14°C to 27°C the surface in an ordinary year.

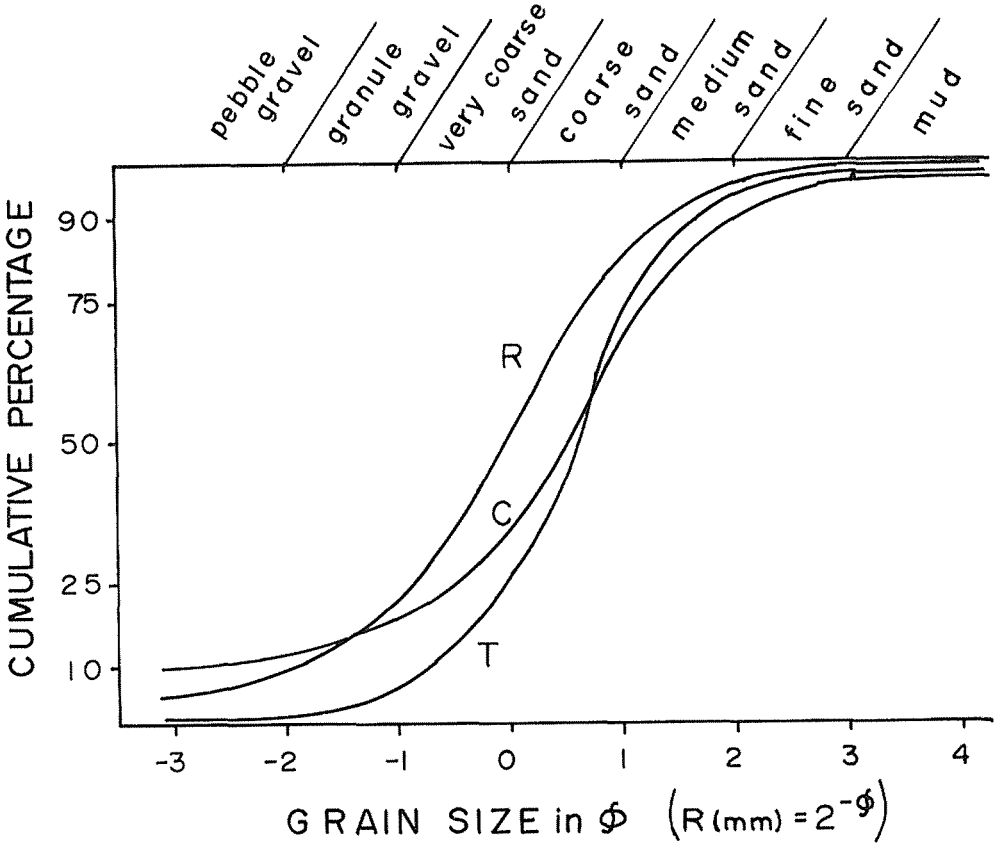

Fig. 2. Cumulative curve of grain size in phi of bottom sediments around the three artificial fish-reefs in Kata Bay.
Abbreviations: R, quarry rock fish-reef; C, concrete fish-reef; T, tier fish-reef.

Table 1. Outline of grain size composition of bottom sediments around the artificial fish-reefs in Kata Bay.

	Md(mm)	So	Sk	Kq	partition of sand at Md
Quarry rock fish-reef	1.00	1.70	1.06	0.18	very coarse sand-coarse sand
Concrete fish-reef	0.71	1.77	0.95	0.06	coarse sand
Tier fish-reef	0.64	1.30	0.78	0.13	coarse sand

Where So (Coefficient of sorting), SK (Coefficient of skewness) and Kq (Coefficient of kursosis) are obtained in following equations:

$$So = \sqrt{\frac{Q_1}{Q_3}} \qquad Sk = \sqrt{\frac{Q_1 \cdot Q_3}{Md^2}} \qquad Kq = \frac{1}{2}\left(\frac{Q_3 - Q_1}{P_{10} - P_{90}}\right)$$

P_{10}, Q_1, Md, Q_3, P_{90} are diameter at 10%, 25%, 50%, 75% and 90% respectively in cumulative percentage.

Quarry rock fish-reef

this fish-reef was made of 785m^3 of granite in October 1976. Individual rocks weigh about a ton. The fish-reef consists of two hillocks situated at a distance of 7~8m; both the hillocks are about 3m in height from the bottom to the highest point. Shape of the fish-reef is shown by a floor plan and a sectional one along the north-south line across the peak of each hillock in Fig. 3.

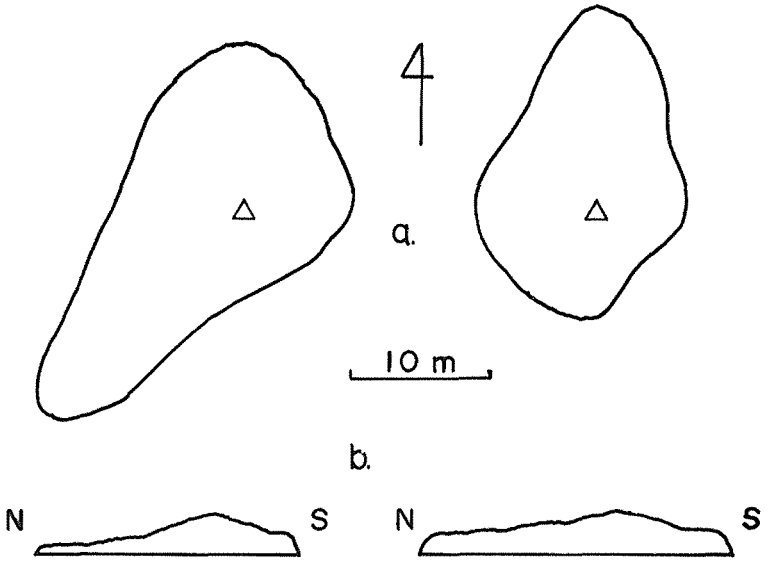

Fig. 3. An Outline map of the study quarry rock fish-reef in Kata Bay. a. floor plans of two hillocks in situ., b. sectional plans of same in north-south line across respective peaks.

Concrete shelter fish-reef

This fish-reef was constructed of 124 concrete shelters in March 1975; a unit

concrete shelter is cube with a side of 1.2m and ca. 1.5 tons in weight, (Fig. 4). The concrete shelters are heaped up forming a hillock except some shelters dispersed nearby; the hillock rises to a height of some 5m. Shape of the fish-reef is illustrated by a floor plan and a sectional one along the north-south line across the peak in Fig. 5.

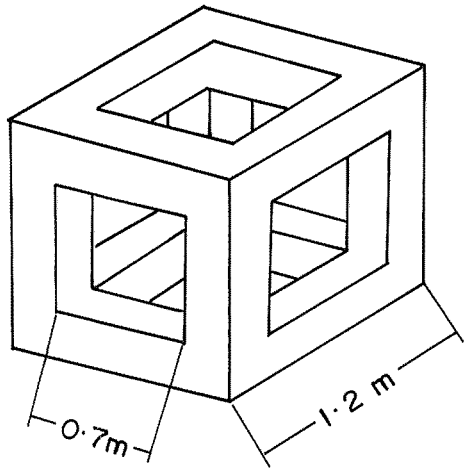

Fig. 4. A sketch of a concrete shelter. It weighs ca. 1.5 tons.

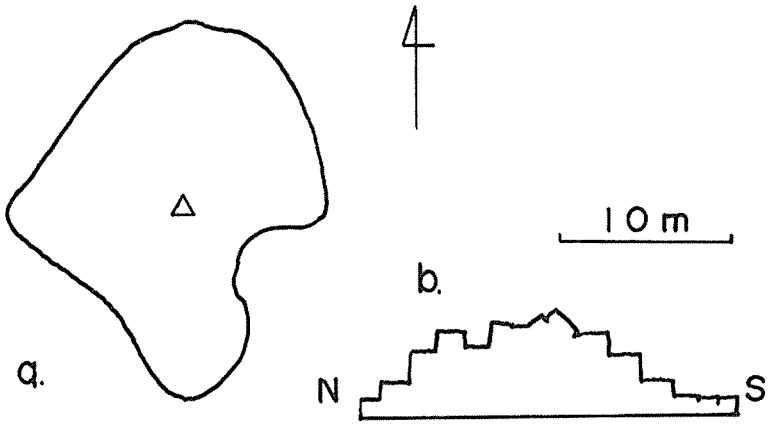

Fig. 5. An Outline map of the study concrete shelter fish-reef in Kata Bay.
a. a floor plan of the fish-reef, a few shelters dispersed were neglected.
b. a sectional plan of same in north-south line across the peak.

Tier shelter fish-reef

This fish-reef was constructed of a total of 259 units of tier shelters from December 1973 through November 1975, and besides some five wooden ships 10~20m in length which were weighted with quarry rocks were added during 1974-1976, (Table 2). Two

types of unit shelters TB-type and LT-type, are used in this fish-reef; the names of types, TB and LT, are referred to as track or bus and little track respectively. A unit shelter is constructed by connecting three rows of tiers as illustrated in Fig. 6; each row of tiers which consists of 5 tiers in TB-type and 8 tiers in LT-type are bound with cement poured into the underside about one third of the inner space. One unit shelter is 1.7 tons in weight with a volume of 3.4m^3 and 1.4 tons with 2.6m^3 in TB-type and LT-type respectively.

This tier fish-reef consists of a main hillock and a few groups of unit shelters dispersed around the former which is about 4m in height at the highest point and is accompanied by a wooden ship at the edge. A floor plan of the major parts of the fish-reef is shown in Fig. 7.

Table 2. The process of construction of the three artificial fish-reefs studied here and materials in Kata Bay.

1973	Dec.	tier fish-reef	100 units of TB-type tier shelters
1974	Oct.	tier fish-reef	58 units of TB-type & 25 units of LT-type tier shelters, some five wooden ships of 10–20m in length added during 1974–1976.
1975	Mar.	concrete fish-reef	124 concrete shelters (1.2×1.2×1.2m)
	Nov.	tier fish-reef	76 units of TB-type tier shelters
1976	Oct.	quarry rock fish-reef	785m^3 of granite

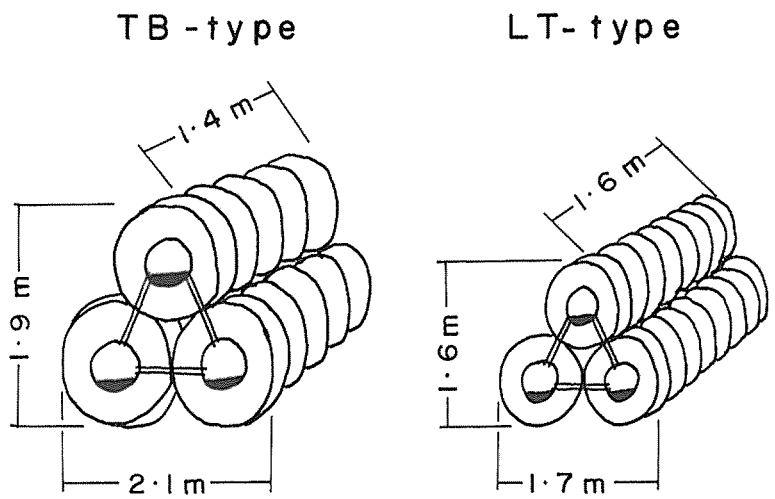

Fig. 6. Sketchs of two types of unit tier shelters. TB-type shelter weighs ca. 1.7 tons, LT-type shelter weighs ca. 1.4 tons.

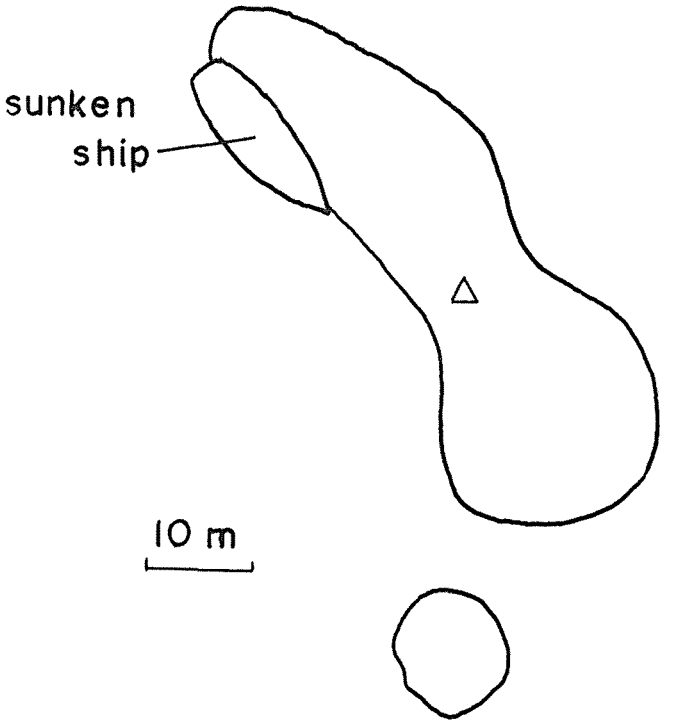

Fig. 7. An outline map of the study tier fish-reef in Kata Bay, a few tier shelters and other sunken ships dispersed around these two major hillocks were neglected.

Encrusting Organisms

Examination of the epifauna and flora covering the surface of the fish-reefs was made on samples collected in September 1977. Up to that time, eleven months had passed in the quarry rocks, 2 years and 6 months in the concrete shelters and from 1 year and 10 months to 3 years and 9 months in the tier shelters after placement of respective fish-reefs. The surfaces of the quarry rocks and the concrete shelters had already been covered almost completely by encrusting organisms, but they had not yet developed sufficiently on the tier shelter leaving the surfaces uncoverd. Flora and epifauna found developed on the fish-reefs are shown in Table 3. Because it is somewhat too deep for algal development, flora of the fish-reefs is generally very scarce. Occurrences of algal species listed in Table 3 are restricted principally only to the most shallow, quarry rock fish-reef. On the other hand, epifauna is composed of many species representing various invertebrate groups. That, most abundanthly spread over the surfaces of the fish-reefs were tube-worms (Polychaeta, Sedentaria) and moss animals (Bryozoa), especially feather-duster worm, *Hydroides norvegica*, and a kind of moss animals, *Caberea late*, are the dominant species. The community of encrusting organisms on the fish-reefs is referred to as feather-duster worms-moss animals complex.

Table 3. Flora and epifauna of the three artificial fish-reefs in Kata Bay (in Sept. 1977).

Phylum	Species
	[Algae]
Chlorohycophyta	
	Codium mamillosum Harvey
Phaeophycophyta	
	Eckloniopsis radicosa (Kjellman)
Rhodophycophta	
	Delisea fimbriata (Lamouroux)
	Martensis denticulata Harvey
	Corallinaceae spp.
	[Animals]
Protozoa	
	Baggina philippinensis (Cushman)
	Homotrema rubrum (Lamarck)
	Miniacina miniacea (Pallas)
Porifera	
	Sycon okadai Hozawa
	Callyspongia elongata (Ridley & Dendy)
	Tetilla aurantia (Pallas)
Coelenterata	
	Sarcophyton elegans Moser
	Dendronephthya gigantea (Verrill)
	D. habereri Kükenthal
	Stereonephthya rubriflora Utinomi
	Acalycigorgia inermis (Hedlund)
	Melithaea flabellifera (Kükenthal)
	Parasicyonis actinostolodes (Wassilieff)
Platyhelminthes	
	Stylochus ijimai Yeri & Kaburaki
Mollusca	
	Nordotis sp.
	Monoplex australasiae echo (Kuroda & Habe)
	Mancinella echinata (Blainville)
	Turris crispa Lamarck
	Ergalatax contractus calcareus (Dunker)
	Teredinidae sp.
Annelida	
	Harmothoë imbricata (Linné)
	Sylidae spp.
	Genetyllis castanea (Marenzeller)
	Eumida sanguinea (Oersted)
	Phyllodocidae sp.
	Nereidae spp.
	Pomatoleios Kraussii (Baird)
	Protula tubularia (Montagu)
	Hydroides norvegica Gunnerus
	Spirobranchus giganteus (Pallas)
	Dexiospira foraminosus (Bush)
	Salmacina dysteri (Huxley)
Arthropoda	
	Ostracoda spp.
	Copepoda spp.
	Megabalanus rosa (Pilsbry)
	Balanus trigonus Darwin
	B. reticulatus Utinomi
	Janiropsis longiantennata Thielemann
	Paranthura japonica Richardson
	Limnoria andrewsi Calman
	Nippochelura brevicauda (Shiino)
	Gammaridea spp.
	Caprella rhopalochir Mayer
	Portunus pelagicus (Linné)
	Calcinus sp.
Tentaculata	
	Aetea anguina (Linné)
	Membranipora savartii (Audouin)
	Caberea lata Busk
	Beania mirabilis Johnston
	Fenestrulina mutabilis (Hastings)
	Escharella immersa (Fleming)
	Dakaria subovoidea (D'Orbigny)
	Celleporaria tridenticulata (Busk)
	Celleporina porosissima Harmer
	Smittina sp.
Echinodermata	
	Asthenosoma ijimai Yoshiwara
	Diadema setosum (Leske)
	Texopneustes pileolus (Lamarck)
	Holothuria pervicax Selenka
Protochordata	
	Herdmania momus (Savigny)
	Styela plicata (Lesueur)

The wooden ships added to the tier shelters have furnished wood-boring organisms and some kinds of polychaets and crustaceans with suitable habitats. Besides aggregations of shipworm, teredinids species (Mollusca, Pelecyopoda), and wood-boring crustaceans, *Limnoria andrewsi*, (Isopoda) and *Nippochelura brevicauda*, (Amphipoda), some other kinds of isopods, gammarids and polychaets were found in abundance on the wooden portions of the ships. These rich organisms on the ship shelters seemed to compensate for the scarcity of encrusting organisms on the tier selters.

During the succeeding surveys, though the species composition of the commuity unaltered noticeably, encrusting organisms of the fish-reefs increased gradually in amount, especially on the quarry rocks and the concrete shelters. Of algae, especially a brown alga, *Eckloniopsis radicosa*, was observed to have incresased greatly, both in the number and size, althugh the distribution was restricted to only within the most shallow quarry rock fish-reef the same as in the first biological survey, september 1977. Soft corals (Alcyonacea) and hony corals (Gorgonacea) also grew gradually on the quarry rocks and the concrete shelters. Whereas encrusting organisms on the tier shelters did not develop noticeably leaving yet uncovered surfaces of tiers. The wooden ships collapsed rapidly owing mainly to the action of wood-boring organisms. The life span of wooden ships is very short, being 5–6 years at the most.

Fish community

A total of 81 species, representing 41 families and 64 genera, were recorded during our observations (Table 4). Of 81 species, 55 species, 59 species and 47 species were observed on the quarry rock fish-reef, the concrete fish-reef and the tier fish-reef respectively. Though it seems likely that the number of species found around the fish-reef decrease as the distance from the coast and the depth of the fish-reef increase, here we reserve space to examine the distribution of respective species within the fish-reef area, as the number and the intensity of observations were not always even in the respective fish-reefs.

Fishes associated with the artificial fish-reef are classified variously by different workers (Kawana 1959, Ogawa 1968, Turner *et al.* 1969, Kakimoto 1973, Sakai 1973), but for convineance we classified them into three categories, adopting the names of visitor, transient and resident. This terminology is used generally in the study of the fish community of coral reefs. For the present purpose we define three categories of fishes as follows.

Visitor

Fishes of this category are usually pelagic or active swimmers occupying mid- or upper-water column, which have not a definite home range but migrate broadly in forming large schools generally. Their relationship to the fish-reef is rather incidental. They hardly ever cling to a particular fish-reef and leave eleswhere after a short period

Table 4. Fishes observed on the three artificial fish-reefs in Kata Bay, during 1977–1980. Abbreviations: R, quarry rock fish-reef; C, concrete fish-reef; T, tier fish-reef.

Family	Species	Observed place	Category of fish
Dussumieridae	(round herrings)		
	Spratelloides gracilis (Schlegel)	R, C, T	Visitor
Clupeidae	(herrings and sardines)		
	Sardinops melanosticta (Temminck&Schlegel)	R, C, T	Visitor
Engraulidae	(anchovies)		
	Engraulis japonicus (Houttuny)	R, C, T	Visitor
Plotosidae	(sea catfishes)		
	Plotosus anguillaris (Lacépède)	R, C	Resident
Muraenidae	(moray eels)		
	Gymnothorax kidako (Temminck & Schlegel)	C, T	Resident
Synodontidae	(lizardfishes)		
	Synodus variegatus (Lacépède)	R, C	Transient
Sphyraenidae	(barracudas)		
	(?) *Sphyraena japonica* Cuvier & Valencieness	C	Visitor
Holocentridae	(squirrefishes)		
	Myripristis murdjan (Forsskål)	R	Resident
Oplegnathidae	(beakperches)		
	Oplegnathus fasciatus (Temminck & Schlegel)	R, C, T	Transient
Mullidae	(goatfishes)		
	Upeneus bensasi (Temminck & Schlegel)	T	Transient
	Parupeneus fraterculus (Cuvier & Valenciennes)	C, T	Transient
Apogonidae	(cardinalfishes)		
	Apogon endekataenia Bleeker	R, C	Resident
	A. doederleini Jordan & Suyder	R, C, T	Resident
	A. semilineatus Temminck & Schlegel	R, C, T	Resident
	A. notatus (Houttuyn)	C, T	Resident
Pomatomidae	(bluefishes)		
	Scombrops boops (Houttuyn)	T	Visitor
Serranidae	(groupers and seebasses)		
	Epinephelus areolatus (Forsskål)	R, C, T	Resident
	E. chlorostigma (Cuvier & Valenciennes)	R, C	Transient
	E. latifasciatus (Temminck & schlegel)	R, C, T	Transient

Table 4. *(continued)*

Family	Species	Observed place	Category of fish
	E. septemfasciatus (Thunberg)	R, T	Trarsient
	E. sp.	C	Transient
	Sacura margaritaceus (Hilgendcrf)	T	Resident
Sciaenidae	(drums)		
	Argyrosomus argentatut (Houttuyn)	C	Visitor
Girellidae	(nibblers)		
	Girella punctata Gray	R, C, T	Transient
Gerridae	(majarras)		
	(?) *Gerres oyena* (Forsskål)	C	Visitor
Sparidae	(porgies)		
	(?) *Evynnis japonica* Tanaka	C	Visitor
	Sparus sarba (Temminck et Schlegel)	C	Visitor
Lutjanidae	(snappers)		
	Lutjanus russelli (Bleeker)	R, C, T	Transient
	L. vitta (Quoy et Gaimard)	C	Transient
Pomadasyidae	(grunts and sweetlips)		
	Parapristipoma trilineatum (Thunberg)	R, C, T	Transient
	Plectorhynchus pictus (Thunberg)	R, C, T	Transient
Cirrhitidae	(hawkfishes)		
	Cirrhitichthys aureus (Temminck & Schlegel)	R, C, T	Resident
Cheilodactylidae	(morwongs)		
	Goniistius zonatus (Cuvier & Valenciennet)	R, C, T	Transient
	G. zebra (Döderlein)	R, C, T	Transient
Carangidae	(jacks)		
	Trachurus japonicus (Temminck & Schlegel)	R, C, T	Visitor
	Selar crumenophthalmus (Block)	C	Visitor
	Longirostrum delicatissims (Döderlein)	R, C	Visitor
Mugiloididae	(sandperches)		
	Parapercis sexfasciata (Temminck & Schlegel)	R	Resident
	P. multifasciata Steindachner & Döderlein	R	Resident
	P. pulchella (Temminck & Schlegel)	R, C, T	Resident
Ammodytidae	(Sand lances)		
	(?) *Ammodytes personatus* Girard	R	Visitor
Gobiidae	(gobies)		
	Vireosa hanae Jordan et Starks	R, C	Resident

Table 4. (*continued*)

Family	Species	Observed place	Category of fish
	Acanthogobius sp.	R, C, T	Resident
Embiotocidae	(surfperches)		
	Ditrema temmincki Bleeker	R, C	Transient
Pomacentridae	(damselfishes)		
	Chromis notatus (Temminck & Schlegel)	R, C, T	Resident
	Abubefduf sordidus (Forsskål)	R	Resident
Labridae	(wrasses)		
	Choerodon azurio (Jordan & Snyder)	R, C, T	Transient
	Thalassoma cupido (Temminck & Schlegel)	R	Resident
	Pteragogus flagelifera (Cuvier & Valenciennes)	T	Resident
	Pseudolabrus japonicus (Houttuyn)	R, C, T	Resident
	Labroides dimidiatus (Cuvier & Valenciennes)	R, C, T	Resident
	Halichoeres tenuispinus Gunther	R, C	Resident
	H. Poecilopterus (Temminck & Schlegel)	R, C, T	Resident
	Cirrhilabrus temmincki Bleeker	R, C	Resident
Scaridae	(parrotfishes)		
	Calotomus japonicus (Cuvier & Valenciennes)	R, C	Transient
Scorpididae	(stripey)		
	Microcanthus strigatus (Cuvier & Valenciennes)	R, C, T	Transient
Chaetodontidae	(butterflyfishes)		
	Chaetodon auriga Forskål	R, T	Resident
	C. modestus Temminck et Schlegel	R, C, T	Resident
	C. collare Block	R, C, T	Resident
	C. lunula (Lacépède)	C, T	Resident
	C. nippon Steindachner & Döderlein	R, C, T	Resident
(?)	*Hemitaurichthys* polylepis (Bleeker)	C	Resident
	Heniochus acuminatus (Linnaeus)	R, C, T	Resident
Zanclidae	(mooring idols)		
	Zanclus cornutus (Linnaeus)	R, T	Resident
Acanthuridae	(surgeonfishes)		
	Acanthurus dussumieri Cuvier & Valenciennes	R	Transient
	Prionurus microlepidotus Lacépède	R, T	Transient
Aluteridae	(filefishes)		

Table 4. (*continued*)

Family	Species	Observed place	Categcry of fish
	Stephanolepis cirrhifer (Temminck & Shlegel)	R, C, T	Resident
	Navodon modestus (Günther)	R, C, T	Transient
Ostraciontidae	(trunfikshes)		
	Ostracion cubicus Linneus	R, C, T	Resident
	Lactoria cornutus (Linneus)	T	Resident
	L. diaphanus (Block & Schneider)	C	Resident
Tetraodontidae	(puffers)		
	Canthigaster rivulatus (Temminck & Schlegel)	R, C, T	Resident
	Fugu sp.	T	Resident
Scorpaenidae	(scorpionfishes and rockfishes)		
	Sebastes joyneri Günther	T	Resident
	Sebastiscus marmoratus (Cuvier & Valenciennes)	R, C, T	Resident
	Scorpaenopsis cirrhosa (Thunberg)	C	Resident
	Pterois lunulata Temminck & Schlegel	C	Resident
Synanceiidae	(stonefishes)		
	Inimicus japonicus (Cuvier & Valenciennes)	R	Resident
Hexagrammidae	(greenlings)		
	Hexagrammos otakii Jordan & Starks	R	Resident
Platycephalidae	(flatheads)		
	Platycephalus indicus (Linnaeus)	C	Transient
Cottidae	(sculpins)		
	Pseudoblennius percoides Günther	R	Resident
	Total 41 families, 81 species: Visitor, 13; Transient, 23; Resident, 45.		

Table 5. Comparison of the number of species included into respective categories betweem the three artificial fish-reefs in Kata Bay.

	Visitor	Transient	Resident	Total
Quarry rock fish-reef	6	18	31	55
Concrete fish-reef	11	18	30	59
Tier fish-reef	5	15	28	48

of stay. Visitors observed on the study fish-reefs were 13 species representing 13 families. Most frequently seen were jack mackerel, *Trachurus japonicus*, ranging 15-20cm in total length, silver anchovy, *Spratelloides gracilis*, sardine, *Sardinops melanosticta*, and anchovy, *Engraulis japonicus*. Since visitors stay in general only for a relatively short time on a particular fish-reef, and besides it is impossible in actual fact to watch their coming to fish-reef throughout long periods, the probabilities for visitors to be found by diving observation of short times is very low. In fact, sardine, baracuda, *Sphyraena japonica*, pogy, *Evynnis japonica*, and majarra, *Gerres oyena*, are visitors observed through continuous observation for 26 hours by under-water TV from midnight to daybreak. Though pacific mackerel, *Scomber japonicus*, frigate mackerels, *Auxis tapeinosoma* and *A. thazard*, are caught in quantities by set-nets situated nearby the study fish-reefs, these fishes have not yet been found through our observations up to now. Neverthless, these species are ichthyovores or fish sharing considerable ichthyovorous habts, therefore it is probable that they must associate with the fish-reefs as barracuda through such intermeditors; being bait, as sardines, anchovies, cardinal-fishes and other small fishes.

Transient

Fishes included in this category are reef associated or reef oriented fish, and are moderate swimmers, occupying mid- or lower-water column. They wander extensively in general, throughout adjoining reef areas or from reef to reef, some of them migrate in forming schools. Besides, as benthic fish living usually on a sandy bottom connect also variously with artificial fish-reefs, here we include them as transient or resident according to the extent of their travelling.

Twenty-three species representing 15 families found on the study fish-reefs were included in this category. Typical and usually seen transients are beackperch, *Oplegnathus fasciatus*, goatfish, *Parupeneus fraterculus*, groupers or seabasses, *Epinephelus culorostigma*, *E. latifasciatus* and *E. septemfasciatus*, nibble, *Girella punctata*, snappers, *Lutzanus russeli* and *L. vitta*, grunt, *Parapristipoma trilineatum*, sweetlip, *Plectorhynchus pictus*, morwongs, *Goniistius zonatus* and *G. zebra*, surfperch, *Ditrema temmincki*, wrass, *Choerodon azurio*, parrotfish, *Calotomus japonicus*, stripy, *Microcanthus strigatus*, surgeonfish, *Prionurus microlepidotus*, and filefish, *Navodon modestus*. The majority of transients are important commercial fishes. Especially grunt is one of the most important fishes, and it aggregates frequently to artificial fish-reefs forming large school occasionally.

Resident

Fishes included in this category are those that strongly cling to the reef areas in general, having a relatively narrow home range. They are inactive swimmers and essentially non-migrators. And besides many of them share the characteristic of being strongly territorial or at least having a well-defined home range.

Forty-five species representing 17 families seen on the study fish-reefs were included

in this category. Typical and most frequently seen residents are cardinalfishes, *Apogon semilineatus* and *A. notatus*, moray eel, *Gymnothorax kidako*, grouper, *Epinephelus areolatus*, hawkfish, *Cirrhichthys aureus*, gobies, damselfish, *Chromis notatus*, wrasses, *Halichoeres tenuispinus* and *H. poecilopterus*, batterflyfishes, *Chaetodon collare* and *C. nippon*, filefish, *Stephanolepis cirrhifer*, trunkfish, *Ostracion cubicus*, puffer, *Canthigaster rivulatus*, rockfish, *Sebastiscus marmoratus*, and sculpin, *Pseudoblennius percoides*. As resident fishes spend almost the whole period of their lives within a definite reef area, we can easily find them and watch their behavior except for some nervous or cryptic species. Neverthless, as our observations have been carried out to lay emphasis on commercial fishes, some valueless, cryptic and rare fishes must have been overlooked. Except for a few kinds of groupers or seabasses, rockfishes, the majority of residents ane non- or less-commercial fish.

Discussion

Out of consideration for the results of our observations and knowledge of a mode of life of respective species, we classified all the species observed on the study fish-reefs, into three categories. The classification of respective fish is, however, unrigid. Especially for some fishes being on the border between visitor and transient, and between transient and resident are undefinable clearly in acutual fact, then categorizing them is due to our subjectivity, to some extent. As inshore fish exhibit extreme diversity in their mode of life or behavior, moreover those are not always even throughout their lives, it is impossible and does not fit in the reality to classify too strictly.

Turner *et al.* (1969), in their ecological studies on multi-compoment artificial fish-reefs placed 60-foot deep in Santa Monica Bay, have classified 78 species (35 families and 60 genera) observed on the fish-reefs into four categories, they are pelagic fishes, benthic fishes, semi-resident fishes and resident fishes. As roted before, we did not make a category "benthic", but included benthic fish into transient or resident, according to the extent of their movement on account of the fact that they are also attracted to artificial fish-reefs to some extent. Three categories, of visitor, transient and resident, defined here, almost correspond to pelacic, semi-resident and resident by Turner *et al.* (1969) except on the point of benthic fishes.

Aside from the strict definition of fish-categories, classification of fish on artificial fish-reefs is available for an actual purpose. Of fishes which have some relationship to artificial fish-reefs even if it is incidental, commercial fish are almost all referred to visitor and transient except a few resident fish. Therefore, the number of species of visitors and transients coming on artificial fish-reefs can be regarded as a scale expressing reef-effects.

Comparison of the number of species belonging to respective categories between three artificial fish-reefs studied here (Table 5), indicates that the number of species

of visitors is the most on the concrete fish-reef, the highest one of the three. Moreover, we have some instances that no visitor nor any fish assemblage was found on the artificial fish-reefs, in which unit shelters were not piled up, but scattered on the sea floor. From the above, we consider that the height of the artificial fish-reef is one of the important factors yeilding sufficient reef-effects, at least for visitors and transients migrating in upper- or mid-water column.

Acknowledgments

We wish to express our cordial thanks to Prof. K. Suzuki and prof. T. Nonoda of this faculty for their various advice and encouragement. Hearty thanks also due to the members of both the Fisheries Co-opratives of Furue and Mikiura, Owase City, and the staffs of the Fisheries, Commerce & Industry Section of Owase City, and also to Mr. M. Yuasa and Mr. O. Suenaga, students of those days of this faculty, for all the gentlmen's indispensable support in carrying out the surveys. We slso wish to acknowledge that the surveys have been undertaken with the aid of grants from the Fisheries, Commerce & Industry Section of Owase City and from the Agriculture & Fisheries' Department of Mie Prefecture.

References

CARLISLE, J. G. Jr., 1962. Housing scheme for fishes. *Sea Frontiers*. 8(2): 68-75.

HIGO, N. *et al.* 1979. On the fish gathering effect of the artificial reefs ascertained by the diving observation-III. At the off sea of Taniyama, Kagoshima City. *Mem. Fac. Fish., Kagoshima Univ.*, (28): 91-105. (In Japanese).

KAKIMOTO, H., 1967. On the effective areas of the artifical reefs. *Aguiculture*, 14(4): 181-190. (In Japanese).

————, 1973. Vertical distribution of fishes on artificial reefs. quoted from A review of artificial fishreef research-I. primary subjects of artificial fishreef study. by the Synthetic Research Society of Artifical Fishreef. Japanese Fisheries Resorces Conservation Association, Aquiculture Book Series, 26: 1-119. (In Japanese).

KAWANA, T., 1959. quoted form above book. (In Japanese).

KATAOKA, T. and Y. TOMIDA, 1981. Fish fauna of Mie Prefecture. *Bull. Mie. Mus. (Nat.)*, (3): 1-110, (In Japanese).

MASUDA H., C. ARAGA and T. YOSHINO, 1975. Coastal fishes of Souther Japan. Tokai Univ. Press., 1-379.

MASUZAWA, H. 1968. The productive effect to reef fishes. *Aquiculture Extra* (7): 67-82. (In Japanese).

OGAWA, Y., 1968. The artificial fish reefs and concentrating of fishes to them. *Ibid* (7): 3-22. (In Japanese).

ŌHSHIMA, Y., 1964. Housing scheme for fishes. Japanese Fisheries Resorces Conservation Association, Aguiculture Book Series, 8: 1-56. (In Japanese).

OKAMOTO, T., T. KUROKI and T. MURAI, 1979. Preliminary studies on the ecology of fishes near artificial reefs-Outline of the artificial reefs off Sarushima Island. *Bull. Jap. Soc. Sci. Fish.*, 45 (6): 709-713. (In Japanese).

———— and ————, 1979. Fundamental studies on the ecology of fishes near artificial reefs-I. Preparatory observation of fish amount. *Ibid.*, 45(9): 1085-1090. (In Japanese).

SAITO, A., 1968. The productive effect to migratory fishes. *Aguiculture Extra* (7): 83-98. (In Japanese).

SAKAI, T., 1973. Note of the gathering style and living place at artificial fish reefs. *Bull. Fish. Exp. Sta. Hyogo-Ken*, (13): 31-33. (In Japanese).

SAWADA, T., C. MIYAZAKI and T. SHIBATA, 1975. The effect of artificial fish reefs on the fishing efficiencies of set net. *Bull. Fish. Exp. Sta. Shizuoka Pref.*, (9): 1-15. (In Japanese).

SHIINO, S. M., 1972. List of English names of Japanese fish with proposition of new names. *Sci. Rep. shima. Marinland*, (1): 1-210, Pl. I.

————, 1976. List of common names of fish of the world, those prevailing among English-speaking nations. *Ibid.*, (4): 1-262.

SMITH, C. L., 1973. Small rotenone station: A tool for studying coral reef fish communities. *Amer. Mus. Novitates*, (2512): 1-21.

——— and J. C. TYLER, 1973. Population ecology of a bahamian suprabenthic shore fish assemblage. *Ibid.*, (2528): 1-38.

——— and ———, 1975. Succession and stability in fish communities of dome-shaped patch reefs in the west Indies. *Ibid.*, (2572): 1-18.

SYNTHETIC RESEARCH SOCIETY of ARTIFICIAL FISHREEF, 1976. A review of artificial fishreef research-I. Primary subject of artificial fishreef study. Japanese Fisheries Resorces Conservation Association, Aquiculture Book Series, 26:1-119. (In Japanese).

————, 1976. Ditto -II. Present status in research of artificial fishreef. *Ibid.*, 27: 1-126. (In Japanese).

TURNER, C. H., E. E. EBERT and R. R. GIVEN, 1969. Man-made reef ecology. *Fish. Bull.*, (146): 1-221.