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Nearshore ichthyofauna in the intermediate sandy beach, Doigahama Beach, Yamaguchi Prefecture, Japan

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The ichthyofauna in the nearshore zone of a protected and microtidal sandy beach of Doigahama Beach, Yamaguchi Prefecture, Japan was surveyed. The morphodynamic state of the beach is an intermediate type with an low tide terrace or ridge/runnel. Two kinds of beach seines having different dimensions and mesh sizes were employed and the samplings were carried out through day and night, and at every tidal cycle. A total of 20,401 individuals composed of 62 families and more than 112 species were collected during entire research period from May 1994 to November 2000. The developmental stages of these fishes involved not only larvae and early juveniles but also the late juveniles and adults. *Mugil cephalus cephalus, Lateolabrax latus, Sillago japonica, Paralichthys olivaceus, Paraplagusia japonica* and *Takifugu niphobles* were considered as the nearshore zone resident species in the sandy beach.

1 Introduction

Most of early studies on the ichthyofauna in the nearshore zone (an area extending from the shoreline to just beyond the region in which the waves break; the zone consists of swash, surf and breaker zones seaward)[1] of a sandy beach in Japan have been aimed at the larval and early juvenile fishes[2-4]. On the other hand, the aim of our study group is to carry out entire ichthyofaunal study covering the larvae to adults in the nearshore zone at Doigahama Beach, following the preliminary report on the ichthyofauna at this location published by Uchida et al.[5]. The study group has intensively continued field surveys since 1994 and sufficient data such as many data on additional species and specimens to realize a general view of the nearshore zone ichthyofauna have been obtained. In this paper, we describe the fish species occurring in the nearshore zone at Doigahama with some comments, and also show growth of dominant species. The present study is an unique example of the nearshore zone ichthyofauna because of the relatively longer research period over six years covering every diel and tidal cycles, and the adoption of two sampling gears to collect all the developmental stages and mode of lives.

2 Materials and methods

Doigahama beach (34° 17.0′-17.5′N, 130° 53.0′-53.5′E) of about 1 km in length is located on the western coast of Yamaguchi Prefecture facing westward to the Hibiki-nada Sea (which is southwestern portion of the Sea of Japan) (Fig. 1). This microtidal beach (maximum tide range below 2 m) is enclosed by a rocky headland at the north end and a jetty at the south end, and is classified as a protected beach based on its geomorphological openness[6] to the prevailing wave direction.

The morphodynamic state, one of important indices revealing the overall beach condition[7,8] of Doigahama Beach

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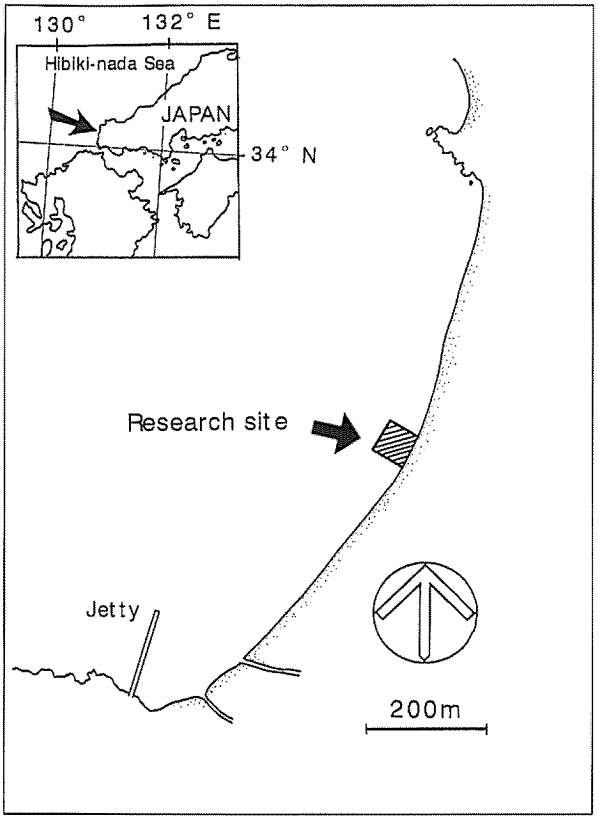

Fig. 1. Map of the research site at Doigahama Beach.

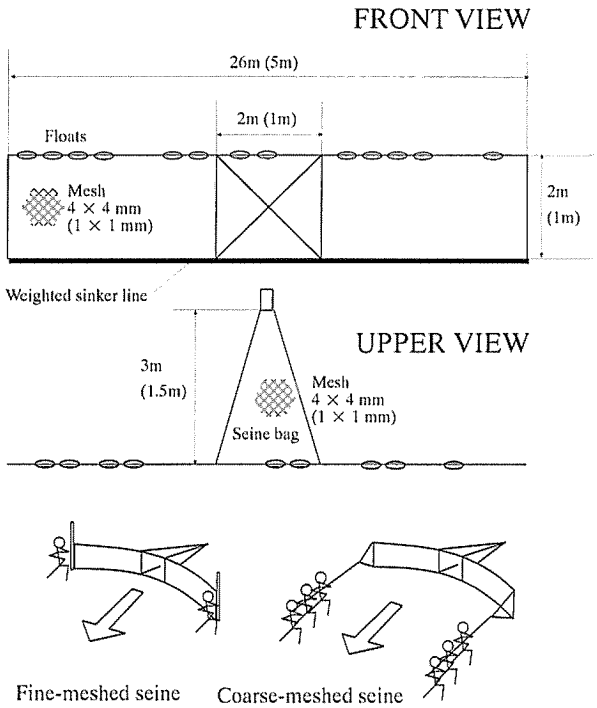

Fig. 2. Sampling gears and the methods of towing. Above: frontal and dorsal views of both coarse- and fine-meshed seines (dimensions of the fine-meshed seine were shown in the parentheses), below: illustrations of the methods of towing.

shows the intermediate type with a low tide terrace or ridge/runnel. The development of a low tide terrace or a ridge/runnel, however, is weak and the maximum depth and width of the runnel is approximately 0.3m and 30m, respectively, at most. Although the beach is moderately exposed (sense Brown and McLachlan[7]), wave breaking is not very evident in a tranquil sea condition. Usually the breaker zone is present 20-30m offshore from the shoreline at high tide, whereas it is not clear at low tide.

The southern part of the beach is in a slightly sheltered (sense Brown and McLachlan[7]) condition compared to the other parts of the beach due to the presence of a jetty and effluents from two small streams. Some chemical features also support it[9]. Three submerged detached breakwaters have been constructed along the 5 - 6 m deep contours in front of the beach during the research period.

Samplings were carried out in the nearshore zone, particularly the surf zone (sense Komar[1]), using two kinds of beach-seines with different dimensions and mesh sizes from May 1994 to November 2000 (Fig. 2). Both seines were towed in the zone by hand. The fine-meshed seine with a 1 mm square mesh was towed 50 m parallel to the shore at the depth of about 0.5- 1 m (totally 1,166 hauls), and the coarse-meshed seine with a 4 mm square mesh was towed shoreward perpendicular to the shoreline from the place with a depth of about 1 m (503 hauls). The bases of both seines are fringed with weighted lines for reducing the escapement of bottom fishes such as flatfishes and solefishes. The sampling was done through day and night, and at every tidal cycle. For details about the sampling operation and occasions, see Suda et al.[10]

Every fish sample was preserved in 10% formalin solution at the site, and then transferred to a 60% ethanol solution after complete primary fixation by formalin. Identification follows Nakabo[11] and Okiyama[12].

The determination of the temporal association[7] was as follows: residents (R), species occurred almost through the year; seasonal migrants (M), species occurred in a particular season of the year; strays (S), species occurred irregularly in the nearshore zone of the sandy beach.

Table. 1. Summary of the categorization of the nearshore zone fishes at Doigahama Beach. PL, postlarva; J, juvenile; A, adult; M, seasonal migrant; R, resident; S, stray; CP, coastal/pelagic; CR, coastal/rocky reef; CS, coastal/sandy bottom; I, inland water; OP, offshore pelagic.

	Developmental stage			Temporal association	Major adult habitat
	PL	J	A		
Mugil cephalus cephalus				R	CP
Lateolabrax latus				R	CP
Takifugu niphobles				R	CP
Sillago japonica				R	CS
Paralichthys olivaceus				R	CS
Tarphops oligolepis				R	CS
Heteromycteris japonica				R	CS
Paraplagusia japonica				R	CS
Sardinops melanostictus				M	CP
Engraulis japonicus				M	CP
Hypoatherina tsurugae				M	CP
Hypoatherina valenciennei				M	CP
Trachurus japonicus				M	CP
Girella punctata				M	CR
Pisodonophis zophistius				M	CS
Trachinocephalus myops				M	CS
Gerres equulus				M	CS
Sparus sarba				M	CS
Acanthopagrus schlegelii				M	CS
Luciogobius sp.				M	CS
Gymnogobius urotaenia				M	CS
Plecoglossus altivelis altivelis				M	I
Ophichthinae sp.				S	-
Anguilloidei spp. (Leptocephalli)				S	-
Anguilloidei sp. (Juvenile)				S	-
Gobiidae spp.				S	-
Elops hawaiensis				S	CP
Etrumeus teres				S	CP
Spratelloides gracilis				S	CP
Konosirus punctatus				S	CP
Crenimugil crenilabis				S	CP
Chelon haematocheilus				S	CP
Iso flosmaris				S	CP
Hyporhamphus intermedius				S	CP
Hyporhamphus sajori				S	CP
Hyporhamphus sp.				S	CP
Tylosurus crocodilus crocodilus				S	CP
Decapterus sp.				S	CP
Kaiwarinus equula				S	CP
Sphyraena sp.				S	CP
Takifugu snyderi				S	CP
Takifugu porphyreus				S	CP
Takifugu reticularis				S	CP
Plotosus lineatus				S	CR
Syngnathus schlegeli				S	CR
Syngnathinae sp.				S	CR
Hippocampus mohnikei				S	CR
Apistus carinatus				S	CR
Sebastiscus marmoratus				S	CR
Sebastes inermis				S	CR
Inimicus japonicus				S	CR
Minous monodactylus				S	CR
Hypodytes rubripinnis				S	CR
Hexagrammos agrammus				S	CR
Hexagrammos otakii				S	CR

Furcina osimae				S	CR
Furcina ishikawae				S	CR
Pseudoblennius marmoratus				S	CR
Pseudoblennius cottoides				S	CR
Pseudoblennius sp.				S	CR
Epinephelus septemfasciatus				S	CR
Apogon semilineatus				S	CR
Apogon sp.				S	CR
Lobotes surinamensis				S	CR
Parapriacanthus ransonneti				S	CR
Pempheris schwenkii				S	CR
Chromis sp.				S	CR
Microcanthus strigatus				S	CR
Labridae sp.				S	CR
Pholis nebulosa				S	CR
Pholis crassispina				S	CR
Springerichthys bapturus				S	CR
Enneapterygius etheostomus				S	CR
Neoclinus bryope				S	CR
Scartella emarginata				S	CR
Petroscirtes breviceps				S	CR
Blenniidae sp.				S	CR
Aspasmichthys ciconiae				S	CR
Aspasma minimum				S	CR
Lepadichthys frenatus				S	CR
Pterogobius zonoleucus				S	CR
Siganus fuscescens				S	CR
Rudarius ercodes				S	CR
Stephanolepis cirrhifer				S	CR
Dysomma anguillare				S	CS
Gnathophis nystromi nystromi				S	CS
Saurida elongata				S	CS
Saurida sp.				S	CS
Synodontidae sp.				S	CS
Myctophidae sp.				S	CS
Chelidonichthys spinosus				S	CS
Lepidotrigla sp.				S	CS
Suggrundus meerdervoortii				S	CS
Hoplichthys sp.				S	CS
Gerres erythrourus				S	CS
Acanthopagrus latus				S	CS
Upeneus japonicus				S	CS
Rhyncopelates oxyrhynchus				S	CS
Ammodytes personatus				S	CS
Repomucenus curvicornis				S	CS
Chaenogobius annularis				S	CS
Chaenogobius gulosus				S	CS
Parachaeturichthys polynema				S	CS
Acanthogobius flavimanus				S	CS
Bathygobius fuscus				S	CS
Kareius bicoloratus				S	CS
Samariscus latus				S	CS
Oryzias latipes				S	I
Bregmaceros sp.				S	OP
Cololabis saira				S	OP
Synagrops philippinensis				S	OP
Psenopsis anomala				S	OP
Platyrhina sinensis				unknown	CS

3 Results

A total of 20,401 individuals composed of 62 families and more than 112 species were collected in the whole research period (Table 1). Following is a list of fish with some annotations. The description is arranged in the following order: scientific name, Japanese name, brief description, if necessary, net kind (F: fine-meshed, C: coarse-meshed), total number of individuals collected, total length range, month and year, day/night (D: daytime sampling, N: nighttime sampling), temporal association (R: resident, M: seasonal migrant, S: stray).

Subclass ELASMOBRANCHII
Order RAJIFORMES
Suborder RHINOBATOIDEI
Family PLATYRHINIDAE
Platyrhina sinensis (Bloch and Schneider)
UCHIWAZAME

This is the only non-teleost fish that was present in the nearshore zone at Doigahama. Although the catch record of the species was strictly limited, juveniles of the species have been occasionally observed by underwater observation during daytime in the warm season.
C: 1 ; 146.9 mm; October 1998; N; temporal association is unknown.

Subclass ACTINOPTERYGII
Order ELOPIFORMES
Family ELOPIDAE
Elops hawaiensis Regan
KARAIWASHI
F: 1 ; 36.1 mm; September 1996; N; S.

Order ANGUILLIFORMES
Suborder ANGUILLOIDEI
Family SYNAPHOBRANCHIDAE
Dysomma anguillare Barnard
MEKURAANAGO
C: 1 ; 31.0 mm; November 1998; D; S.

Family OPHICHTHIDAE
Pisodonophis zophistius Jordan and Snyder
HOTATE-UMIHEBI

The occurrence of this species was strictly limited to the nighttime. The species was the only fish optionally collected by the experimental bottom and floating long-line gears operated in the nearshore zone during the nighttime.
C: 10; 592.5-785.0 mm; April 1998, June 1998, 2000, July 1999, September 1998, 2000, November 2000; N; M.

Ophichthinae sp.
F: 1 ; 30.0 mm; November 1998; D; S.

Family CONGRIDAE
Gnathophis nystromi nystromi (Jordan and Snyder)
GIN-ANAGO
F: 18; 21.8-40.4 mm; November 1998; D, N. C: 1 ; 26.6 mm; November 1998; D; S.

Anguilloidei spp. (Leptocephalli)
F: 26; 6.7-56.5 mm; March 1997, 1999, April 1997, May 1996, June 1997, September 1994, October 1995, 1996, 1997, 1999; D, N. C: 10; 30.0-53.7 mm; November 1998, December 1996; D, N; S.

Anguilloidei sp. (Juvenile)
F: 1 ; 58.3 mm; February 2000; N; S.

Order CLUPEIFORMES
Family CLUPEIDAE
Etrumeus teres (De Key)
URUME-IWASHI
C: 1 ; 41.9 mm; June 1997; N; S.

Spratelloides gracilis (Temminck and Schlegel)
KIBINAGO

The species was collected only twice in the nighttime on 1 September 1998 and is considered to be a rare and stray species in the nearshore zone at Doigahama, although this was the most abundant in number of individuals, accounting for 47% of the total catch by both the fine and coarse-meshed beach seines during the entire research period.
C: 9606; 10.9-67.4 mm; September 1998; N; S.

Sardinops melanostictus (Temminck and Schlegel)
MAIWASHI

Shirasu-larvae occurred during the warm seasons from April to June and September from November.
F: 407; 4.3-33.9 mm; April 1995, 1997, May 1996, 1997, 1998, June 1995, 1996, 1997, September 1996, October 1996, November 1999; D, N, C: 1 ; 67.8 mm; June 1999; N; M.

Konosirus punctatus (Temminck and Schlegel)
KONOSHIRO

The occurrence of this species was rare at Doigahama, although it is dominant in the surf zone of Tosa Bay[3].
F: 1 ; 21.7 mm; June 1997; N, C: 1 ; 231.9 mm; June 2000; N; S.

Family ENGRAULIDAE
Engraulis japonicus (Houttuyn)
KATAKUCHI-IWASHI

The species occurred almost throughout the year (Fig. 3). Larvae of 15 to 20 mm in TL emerge in the nearshore zone first in February thereafter they grow to about 60 mm in TL by the end of the year. Although no larger individuals than 90 mm in TL were collected except for one in February, the schools composed of larger individuals were occasionally visually observed in the nearshore zone.
F: 723; 5.9-59.4 mm; February 2000, April 1995, 1998, May 1994, 1996, 1997, 1998, 1999, June 1994, 1995, 1996, 1997, 1998, 1999, July 1994, 1998, 1999, September 1996, October 1997; almost all D, C: 1425; 30.0-140.7 mm; February 2000, June 1997, 1998, 1999, July 1999, October 1996, 1998, November 1996, 2000, December 1998; D, N; M.

Order SILURIFORMES
Family PLOTOSIDAE
Plotosus lineatus (Thunberg)
GONZUI
C: 77; 101.0-200.2 mm; May 1998, September 1997, 1998, 2000; D, N; S.

Order SALMONIFORMES
Family PLECOGLOSSIDAE
Plecoglossus altivelis altivelis Temminck and Schlegel
AYU

Larvae and juveniles of this amphidromous fish occurred almost throughout the year (Fig. 4). In October, larvae of 10-15 mm in TL occurred in the nearshore zone where they spent their larval and juvenile stages until they reached 60-80 mm in TL in the late spring of the next year. As there is no river in Doigahama except for two very small and frequently closing streams, the schools of fish may migrate to nearby rivers such as the Awano River, 10 km northwest from Doigahama, after May.
F: 114; 10.3-57.8 mm; February 1998, 2000, March 1997, 1999, April 1997, 1998, 2000, May 1996, October 1995, November 1997; D, N, C: 162; 28.6-84.2 mm; February 1998, 2000, March 1997, 1999, April 1997, 1998, 2000, May 1999, June 2000, December 1996; D, N; M.

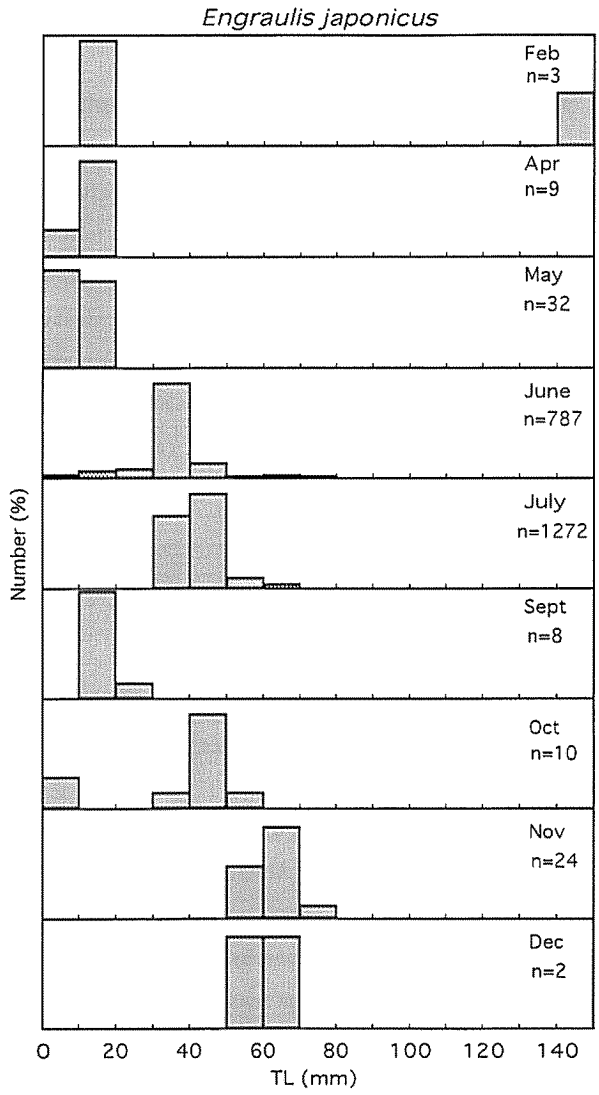

Fig. 3. Monthly changes in the total length frequency distribution of *Engraulis japonicus*. Each monthly frequency distribution is based on the data from the entire research period.

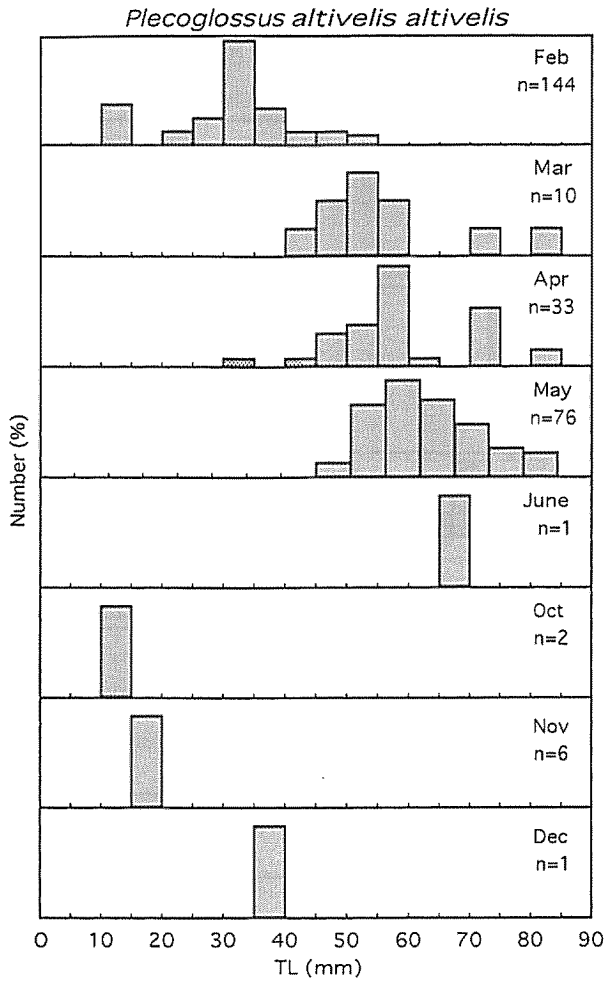

Fig. 4. Monthly changes in the total length frequency distribution of *Plecoglossus altivelis altivelis*. Each monthly frequency distribution is based on the data from the entire research period.

Order AULOPIFORMES

Family SYNODONTIDAE

Synodontidae is typical coastal and offshore sandy bottom fish in its adult stage. However, only the small numbers of juveniles of *Trachinocephalus myops* and pelagic larvae of some other synodontids were collected at Doigahama.

Saurida elongata (Temminck and Schlegel)

TOKAGE-ESO

F: 2 ; 10.0-10.9 mm; September 1997; D; S.

Saurida sp.

MA-ESO

F: 2 ; 18.5-20.3 mm; September 1994, 1997; D, N; S.

Trachinocephalus myops (Schneider)

OKI-ESO

F: 2 ; 5.5-23.9 mm; March 1997, December 1995; D. C: 22; 42.6-123.2 mm; June 1998, July 1998, September 1996, 1997, 1998, 2000; D, N; M.

Synodontidae sp.

F: 3 ; 4.3-6.0 mm; October 1997; D; S.

Order MYCTOPHIFORMES

Family MYCTOPHIDAE

Myctophidae sp.

F: 1 ; 8.5 mm; October 1997; N; S.

Order GADIFORMES

Family BREGMACEROTIDAE

Bregmaceros sp.

F: 3 ; 24.4-44.8 mm; January 1999, September 1998, November 1998; N. C: 1; 32.5 mm; January 1999; N; S.

Order GASTEROSTEIFORMES

Family SYNGNATHIDAE

Syngnathus schlegeli Kaup

YOJI-UO

C: 4 ; 105.2-158.3 mm; June 2000, July 2000, November 2000; D, N; S.

Syngnathinae sp.

F: 1 ; 48.4 mm; October 1999; D; S.

Hippocampus mohnikei Bleeker

SANGOTATSU

F: 2 ; 5.0-26.8 mm; June 1996, November 1998; N; S.

Order MUGILIFORMES

Family MUGILIDAE

Crenimugil crenilabis (Forsskål)

FURAIBORA

F: 1 ; 19.1 mm; July 1998; N. C: 2 ; 150.7-249.3 mm; May 1997, December 1996; D, N; S.

Mugil cephalus cephalus Linnaeus

BORA

F: 30; 26.8-34.8 mm; February 1998, 1999, 2000, March 1999, April 1997, 1998, 1999, May 1996, July 1999, December 1998;

D, N. C: 514; 3.6-291.4 mm; January 1999, February 1997, 1998, 1999, 2000, March 1999, April 1997, 1999, 2000, May 1999, 2000, June 1999, 2000, July 2000, October 1999, November 1999, 2000, December 1996, 1998; D, N; R.

Chelon haematocheilus (Temminck and Schlegel)

MENADA

F: 16; 10.4-23.8 mm; May 1994, June 1995, 1996, 1997, 1998; D, N. C: 5; 17.2-216.9 mm; April 1997, June 1997, 1998; N; S.

Order ATHERINIFORMES

Family ATHERINIDAE

Hypoatherina tsurugae (Jordan and Starks)

GIN-ISO-IWASHI

Early juveniles smaller than 30mm in TL occurred from April to July, grew to about 20-50 mm by October (Fig. 5). The group of 60-80 mm in September and that of 100-120 mm from May to September may be 1-year old and 2-year old fish, respectively, judging from the previous knowledge on the growth of this species[13].

F: 36; 8.9-139.0 mm; April 1995, June 1996, 1998, July 1998, October 1997; D, N. C: 29; 26.9-143. 4 mm; May 1998, June 1998, 1999, 2000, July 1998, September 1998, 2000, October 1997; D, N; M.

Hypoatherina valenciennei (Bleeker)

TOGORO-IWASHI

Early juveniles occurred from July to September, reached about 40-50 mm in TL by October (Fig. 5). The size group of 80-100 mm from May to November may correspond to 2-year old fish. Individuals larger than 100 mm did not occur in the nearshore zone unlike *H. tsurugae*.

F: 50; 11.1-96.8 mm; June 1996, July 1994, 1998, September 1996, 1997, 1998, October 1996; D, N. C: 27; 20.7-99.5 mm; May 1997, 2000, June 1997, 1999, July 1997, October 1996, 1998, November 1996; D, N; M.

Family NOTOCHEIRIDAE

Iso flosmaris Jordan and Starks

NAMINOHANA

F: 5; 8.1-58.0 mm; May 1997, July 1998, November 1994; D, N; S.

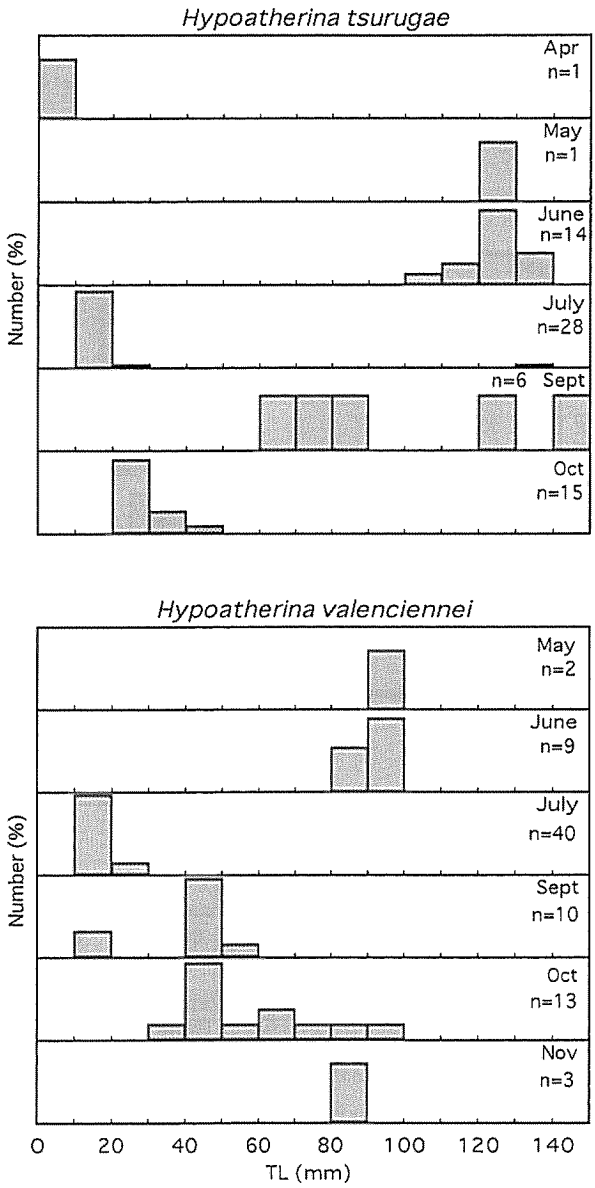

Fig. 5. Monthly changes in the total length frequency distribution of *Hypoatherina tsurugae* and *H. valenciennei*. Each monthly frequency distribution is based on the data from the entire research period.

Order BELONIFORMES

Suborder ADRIANICHTHYOIDEI

Family ADRIANICHTHYIDAE

Oryzias latipes (Temminck and Schlegel)

MEDAKA

This is not a true marine fish and is considered to have moved into the sea from the small streams located in the southern part of the beach.

F: 4; 6.0-28.0 mm; June 1998, July 1998, November 1999; D, N; S.

Suborder EXOCOETOIDEI

Family HEMIRAMPHIDAE

Hyporhamphus intermedius Cantor

KURUMESAYORI

F: 3 ; 39.0-67.0 mm; June 1995, 1996, July 1999; D; S.

Hyporhamphus sajori (Temminck and Schlegel)

SAYORI

C: 2 , 213.9-218.6 mm; October 1996, November 2000; D, N; S.

Hyporhamphus sp.

F: 2 ; 48.6-76.1 mm; June 1998; N. C: 1; 59.0 mm; June 1998; N; S.

Family BELONIDAE

Tylosurus crocodilus crocodilus (Peron and Lesueur)

OKIZAYORI

F: 1 ; 328.0 mm; September 1998; N; S.

Family SCOMBERESOCIDAE

Cololabis saira (Brevoort)

SANMA

F: 2 ; 8.0-8.4 mm; December 1995; D; S.

Order SCORPAENIFORMES

Suborder SCORPAENOIDEI

Family SCORPAENIDAE

Apistus carinatus (Bloch and Schneider)

HACHI

F: 1 ; 16.5 mm; October 1998; N. C: 6 ; 14.8-32.1 mm; October 1998; N; S.

Sebastiscus marmoratus (Cuvier)

KASAGO

F: 1 ; 5.1 mm; April 1998; N; S.

Sebastes inermis Cuvier

MEBARU

F: 2 ; 4.3-24.8 mm; April 1997, December 1997; D, N. C: 1 ; 20.6 mm; March 1998; D; S.

Family SYNANCEIIDAE

Inimicus japonicus (Cuvier)

ONIOKOZE

F: 1 ; 5.7 mm; June 1998; N; S.

Minous monodactylus (Bloch and Schneider)

HIME-OKOZE

F: 1 ; 8.4 mm; May 1997; D; S.

Family TETRAROGIDAE

Hypodytes rubripinnis (Temminck and Schlegel))

HAOKOZE

F: 10; 5.8-8.4 mm; May 1997, June 1996, 1997; D, N; S.

Family TRIGLIDAE

Chelidonichthys spinosus (McClleland)

HOBO

F: 2 ; 17.3-13.5 mm; February 2000, March 1998; D, N. C: 4 ; 16.4-43.0 mm; February 1998, June 1998; D, N; S.

Lepidotrigla sp.

F: 1 ; 12.8 mm; April 1997; N; S.

Family PLATYCEPHALIDAE

Suggrundus meerdervoortii (Bleeker)

MEGOCHI

F: 1 ; 51.9 mm; September 1996; N. C: 1 ; 33.3 mm; September 1996; D; S.

Family HOPLICHTHYIDAE

Hoplichthys sp.

F: 14; 4.2-12.3 mm; May 1997, September 1997, October 1997; D, N. C: 3 ; 59.0-66.4 mm; April 2000, July 2000; D, N; S.

Family HEXAGRAMMIDAE

Hexagrammos agrammus (Temminck and Schlegel)

KUJIME

F: 4 ; 38.0-45.1 mm; February 2000, March 1998, April 1995; D. C: 8 ; 37.0-43.6 mm; February 1998, 2000, March 1998; D, N; S.

Hexagrammos otakii Jordan and Starks

AINAME

C: 1 ; 44.7 mm; March 1999; D; S.

Family COTTIDAE

Furcina osimae Jordan and Starks

KINUKAJIKA

F: 19; 5.4-21.2 mm; February 1997, March 1997, 1998, April 1995, 1997, 1998, 1999, May 1996; D, N. C: 7; 15.3-34.7 mm; March 1997, April 1997; N; S.

Furcina ishikawae Jordan and Starks

SARASAKAJIKA

F: 4 ; 12.6-15.1 mm; March 1997, April 1999; D, N; S.

Pseudoblennius marmoratus (Döderlein)

AYA-ANAHAZE

F: 4 ; 12.1-14.2 mm; February 1998; N. C: 2, 18.3-41.3 mm; March 1997; N; S.

Pseudoblennius cottoides (Richardson)

ASAHI-ANAHAZE

F: 3 ; 16.5-20.0 mm; March 1997; D; S.

Pseudoblennius sp.

F: 1 ; 11.5 mm; April 2000; D. C: 1 ; 17.8 mm; April 2000; N; S.

Order PERCIFORMES

Suborder PERCOIDEI

Family MORONIDAE

Lateolabrax latus Katayama

HIRASUZUKI

This species occurred almost throughout the year (Fig. 6) and is considered to be a resident species in the nearshore zone. The early juveniles of 10-20mm in TL occurred in April and reached about 100 mm by September. Larger individuals of 160-250 mm occurred from September to December, and from 250-320 mm during May to September.

F: 39; 10.1-37.9 mm; April 1995, 1997, 1999, May 1996, 1999, June 1996; D. C: 59; 19.9-308.5 mm; May 1997, 1999, June 1997, 1998, September 1996, 1997, 1998, October 1996, 1997, 1998, November 1998, December 1996; D, N; R.

Family ACROPOMATIDAE

Synagrops philippinensis (Günther)

HIMESUMIKUIUO

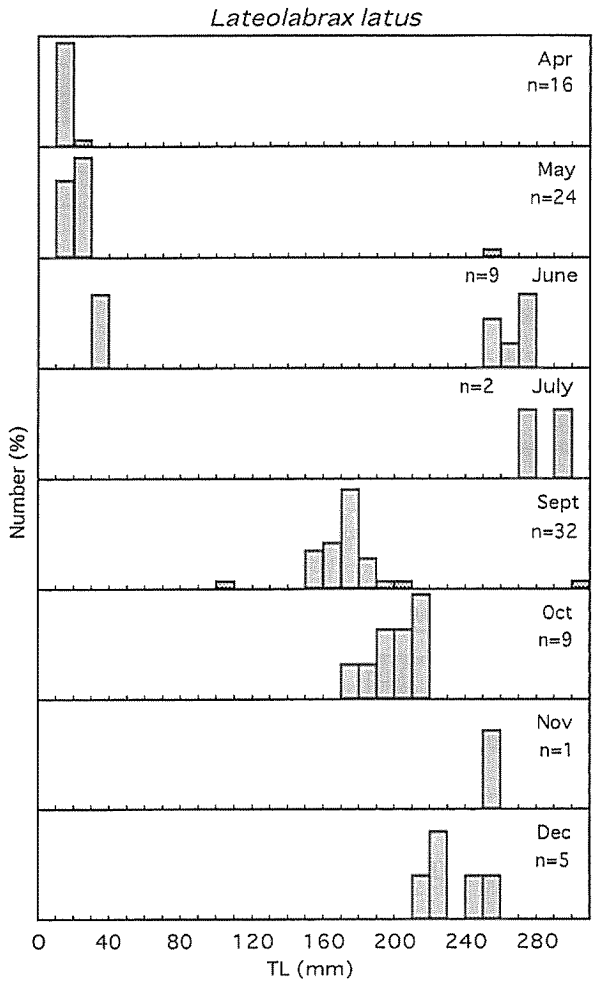

Fig. 6. Monthly changes in the total length frequency distribution of *Lateolabrax latus*. Each monthly frequency distribution is based on the data from the entire research period.

F: 2 ; 6.7-13.7 mm; October 1996, November 1998; N; S.

Family SERRANIDAE

Epinephelus septemfasciatus (Thunberg)

MAHATA

C: 1 ; 42.2 mm; September 1998; D; S.

Family APOGONIDAE

Apogon semilineatus Temminck and Schlegel

NENBUTSUDAI

C: 20; 20.2-34.3 mm; September 1997, October 1996, 1997; N; S.

Apogon sp.

F: 1 ; 21.5 mm; February 2000; D; S.

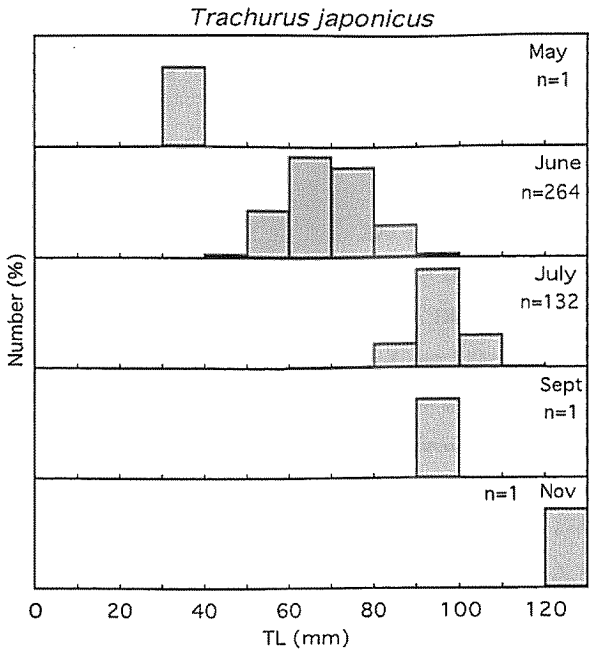

Fig. 7. Monthly changes in the total length frequency distribution of *Trachurus japonicus*. Each monthly frequency distribution is based on the data from the entire research period.

Family CARANGIDAE

Trachurus japonicus (Temminck and Schlegel)

MAAJI

Although we were able to trace the growth of juveniles from May (30-40 mm in TL) to November (120 mm), almost all individuals occurred in June and July (Fig. 7). These juveniles may correspond to the Spring-Summer spawning group[14] in the East China Sea and Tsushima Current System areas. There is another spawning stock in the Sea of Japan (Winter spawning group)[14], but no record of the larvae and/or juveniles originating from this group has been obtained at Doigahama.

F: 13; 56.6-74.0 mm; June 1998; N. C: 389; 30.9-129.8 mm; May 1998, June 1998, 1999, July 1998, 1999, 2000, November 1997; D, N; M.

Decapterus sp.

F: 2 ; 3.6-11.5 mm; October 1997; D; S.

Kaiwarinus equula (Temminck and Schlegel)

KAIWARI

C: 2 ; 102.0-107.8 mm; July 2000; D; S.

Family LOBOTIDAE

Lobotes surinamensis (Bloch)

MATSUDAI

C: 2 ; 20.6-35.9 mm; June 1998, July 1998; D; S.

Family GERREIDAE

Gerres erythrourus (Bloch)

SEPPARISAGI

C: 2 ; 14.5-15.2 mm; October 1998; D; S.

Gerres equulus (Temminck and Schlegel)

KUROSAGI

This was one of the most abundant fish species in the nearshore zone of Doigahama, with only early juveniles presented from September to October with few exceptions of the presence of larvae of 5-6 mm in TL in June.

F: 773; 5.3-14.7 mm; June 1996, 1998, September 1996, 1997, 1998, October 1995, 1996, 1998; D, N. C: 4; 14.6-37.2 mm; September 1998, November 1998, December 1998; D, N; M.

Family SPARIDAE

Sparus sarba (Forsskål)

HEDAI

The early juveniles were present from May to June.

F: 76; 10.8-16.1 mm; May 1996, 1997, 1998, June 1995, 1996, 1997, 1998; D, N. C: 1; 150.7 mm; February 1998; D; M.

Acanthopagrus schlegelii (Bleeker)

KURODAI

This was one of the most abundant species in the nearshore zone of Doigahama, and the postlarvae and early juveniles were present from May to June with few exceptions.

F: 731; 5.4-21.6 mm; May 1996, 1997, 1998, June 1995, 1996, 1997, 1998, 1999, July 1994; D, N. C: 1; 203.0 mm; November 1998; N; M.

Acanthopagrus latus (Houttuyn)

KICHINU

F: 1 ; 12.6 mm; October 1995; D; S.

Family SILLAGINIDAE

Sillago japonica Temminck and Schlegel

SHIROGISU

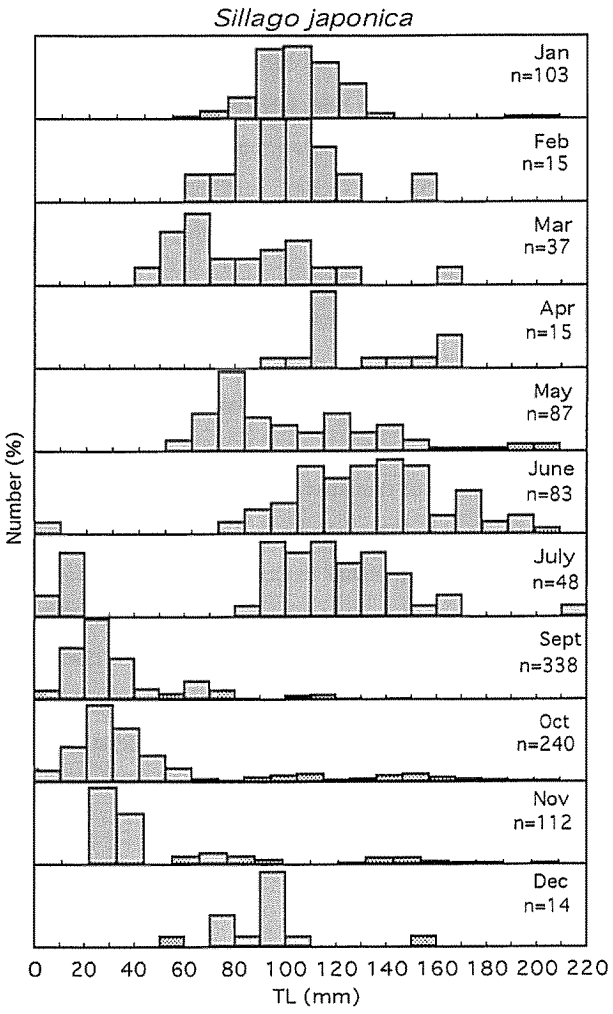

Fig. 8. Monthly changes in the total length frequency distribution of *Sillago japonica*. Each monthly frequency distribution is based on the data from the entire research period.

This was one of typical nearshore zone resident species, and presented through the year (Fig. 8). Judging from the known growth pattern of this species [15], it might utilize the nearshore zone as a habitat for at least three years. Larvae recruited to the nearshore zone community from June to October.

F: 101; 5.8-44.6 mm; June 1996, 1998, July 1994, 1998, September 1994, 1996, 1997, 1998, October 1995, 1996, 1997, 1998; D, N. C: 999; 14.6-217.1 mm; January 1999, February 1997, 1998, 1999, March 1997, 1999, April 1997, 1998, 1999, May 1997, 1998, 1999, June 1997, 1998, 1999, July 1998, 1999, 2000, September 1996, 1997, 1998, 2000, October 1996, 1997, 1998, 1999, November 1997, 1998, 1999, 2000, December 1997, 1998, 1999; D, N; R.

Family MULLIDAE

Upeneus japonicus (Houttuyn)

HIMEJI

F: 1; 31.2 mm; September 1996; D; S.

Family PEMPHERIDAE

Parapriacanthus ransonneti Steindachner

KINMEMODOKI

C: 4; 37.7-43.7 mm; November 2000; N; S.

Pempheris schwenkii Bleeker

MINAMIHATANPO

F: 1; 10.2 mm; October 1995; D; S.

Family POMACENTRIDAE

Chromis sp.

C: 1; 18.1 mm; October 1999; D; S.

Family TERAPONIDAE

Rhyncopelates oxyrhynchus (Temminck and Schlegel)

SHIMA-ISAKI

F: 21; 9.2-12.3 mm; September 1996, 1997, 1998, October 1995; D, N; S.

Family MICROCANTHIDAE

Microcanthus strigatus (Cuvier)

KAGOKAKIDAI

C: 1; 19.0 mm; June 1998; D; S.

Family GIRELLIDAE

Girella punctata Gray

MEJINA

F: 536; 11.2-40.8 mm; April 1995, May 1994, 1996, 1997, 1999, June 1995, 1996, 1997, 1998; D, N. C: 56; 13.2-77.0 mm; May 1997, 1999, 2000, June 1997, 1998, September 1996, 1997; D, N; M.

Suborder STROMATEOIDEI

Family CENTROLOPHIDAE

Psenopsis anomala (Temminck and Schlegel)

IBODAI

F: 1; 7.7 mm; May 1994; D; S.

Suborder LABROIDEI

Family LABRIDAE

Labridae sp.

F: 1 ; 9.1 mm; October 1996; N; S.

Suborder ZOARCOIDEI

Family PHOLIDAE

Pholis nebulosa (Temminck and Schlegel)

GINPO

F: 1 ; 14.2 mm; March 1999; D. C: 1; 44.9 mm; April 1999; N; S.

Pholis crassispina (Temminck and Schlegel)

TAKEGINPO

F: 6 ; 16.1-47.6 mm; March 1997, April 1997, May 1994; D, N; S.

Suborder TRACHINOIDEI

Family AMMODYTIDAE

Ammodytes personatus Girard

IKANAGO

F: 9 ; 28.0-36.8 mm; March 1997, 1999, April 1995; D, N. C: 1 ; 100.0 mm; February 1998; D; S.

Suborder BLENNIOIDEI

Family TRIPTERYGIIDAE

Springerichthys bapturus (Jordan and Snyder)

HIMEGINPO

F: 41; 5.5-16.9 mm; March 1999, May 1996, 1998, June 1994, 1998, July 1998; N; S.

Enneapterygius etheostomus (Jordan and Seale)

HEBIGINPO

F: 86; 5.5-14.4 mm; March 1999, May 1994, 1998, June 1994, 1998, July 1998, September 1998, October 1997; D, N; S.

Family CHAENOPSIDAE

Neoclinus bryope (Jordan and Snyder)

KOKEGINPO

F: 7 ; 16.4-24.0 mm; April 1997, 1998, May 1997; D, N. C: 12; 23.1-26.1 mm; April 1998; N; S.

Family BLENNIIDAE

Scartella emarginata (Günther)

TATEGAMIGINPO

F: 5 ; 12.2-18.5 mm; June 1995, October 1996; D, N; S.

Petroscirtes breviceps (Valenciennes)

NIJIGINPO

F: 31; 13.2-32.8 mm; October 1997, 1999; D, N. C: 53; 13.3-34.1 mm; October 1997, 1999, November 2000; D, N; S.

Blenniidae sp.

F: 1 ; 13.6 mm; October 1999; N; S.

Suborder GOBIESOCOIDEI

Family GOBIESOCIDAE

Aspasmichthys ciconiae (Jordan and Fowler)

TSURU-UBAUO

F: 2 ; 7.3-7.8 mm; May 1997, June 1997; N; S.

Aspasma minimum (Döderlein)

UBA-UO

F: 1 ; 4.0 mm; May 1997; N; S.

Lepadichthys frenatus Waite

MISAKI-UBA-UO

F: 2 ; 6.0-8.7 mm; June 1996, October 1997; N; S.

Suborder CALLIONYMOIDEI

Family CALLIONYMIDAE

Repomucenus curvicornis (Valenciennes)

NEZUMIGOCHI

Although the family Callionymidae *Eleutherochir mirabilis* (Japanese name Bakenumeri) inhabits the sandy bottom close to the shore[11] and has been collected from the surf zone of the open and exposed Hasaki Beach, central Japan[16], so far it had not been found at Doigahama.

C: 2 ; 91.4-104.8 mm; September 1998; D; S.

Suborder GOBIOIDEI

Family GOBIIDAE

Luciogobius sp.

F: 72; 7.4-19.6 mm; May 1994, 1996, 1997, 1998, June 1996, 1997, October 1995, 1996, November 1997; N. C: 1; 40.9 mm; February 1998; N; M.

Chaenogobius annularis Gill

AGOHAZE

F: 20; 10.7-33.0 mm; June 1996, 1997, 1998; N, D. C: 1 ; 27.6 mm; June 1998; N; S.

Chaenogobius gulosus (Guichenot)

DOROME

F: 10; 20.2-32.0 mm; June 1996; D, N. C: 5 ; 21.6-34.4 mm; May 1998, June 1997, 1998; N; S.

Gymnogobius urotaenia (Hilgendorf)

UKIGORI

F: 141; 9.6-36.5 mm; April 1997, 1998, May 1994, 1996, 1997, 1998, June 1996, 1997; D. C: 133; 15.5-39.2 mm; April 1997, 1998, May 1997, 1998, 1999, June 1997, 2000; D, N; M.

Parachaeturichthys polynema (Bleeker)

HIGEHAZE

F: 3 ; 6.4-7.8 mm; October 1995; N; S.

Acanthogobius flavimanus (Temminck and Schlegel)

MAHAZE

F: 8 ; 9.0-16.7 mm; June 1998, July 1994, September 1994, 1998, October 1997; D, N; S.

Pterogobius zonoleucus Jordan and Snyder

CHAGARA

C: 41; 52.3-62.1 mm; November 2000; N; S.

Bathygobius fuscus (Rüppell)

KUMOHAZE

F: 1 ; 6.7 mm; July 1998; N; S.

Gobiidae spp.

F: 34; 5.8-27.0 mm; May 1996, June 1994, 1996, 1998, July 1998, September 1996, 1998, October 1995, 1996, 1998, November 1998; D, N. C: 2 ; 41.5-111.0 mm; February 1997, October 1997; N; S.

Suborder ACANTHUROIDEI

Family SIGANIDAE

Siganus fuscescens (Houttuyn)

AIGO

C: 8 ; 31.5-39.4 mm; October 1996; D, N; S.

Suborder SCOMBROIDEI

Family SPHYRAENIDAE

Sphyraena sp.

F: 1 ; 40.2 mm; July 1999; N; S.

Order PLEURONECTIFORMES

Family PARALICHTHYIDAE

Paralichthys olivaceus (Temminck and Schlegel)

HIRAME

This was another typical resident species at Doigahama Beach and utilized the nearshore zone mainly from April to December (Fig. 9). In April and May a small number of

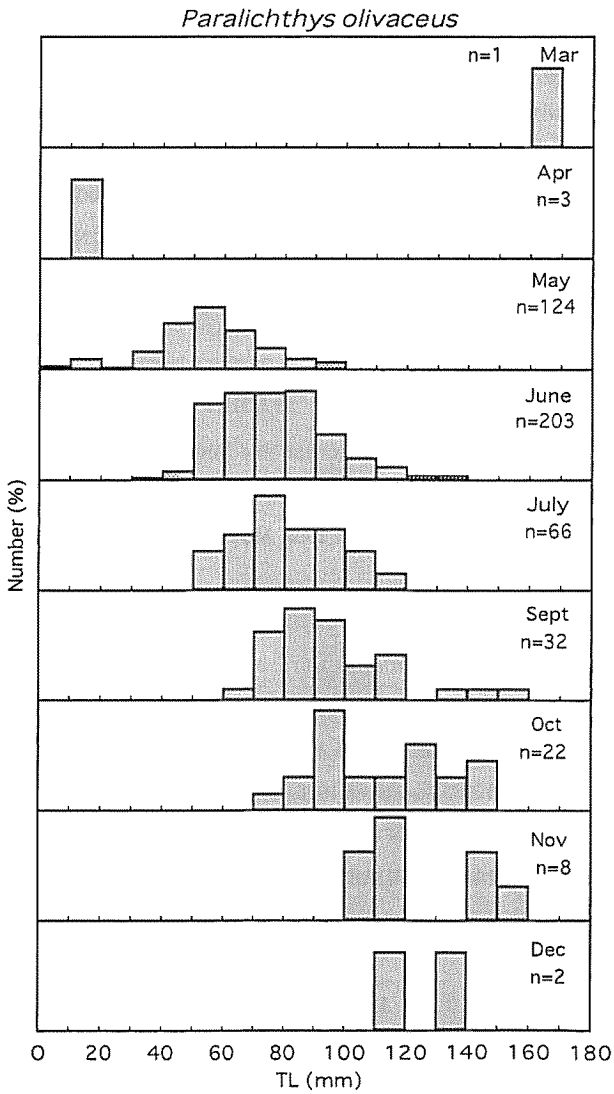

Fig. 9. Monthly changes in the total length frequency distribution of *Paralichthys olivaceus*. Each monthly frequency distribution is based on the data from the entire research period.

the larvae in the developmental stage from pelagic to settlement with TL of 7 -20 mm occurred in the nearshore zone. Thereafter, we were clearly able to trace their growth to the end of the year when the fish reached 100-160 mm in TL. The fish then disappeared from the surf zone during the coldest winter season. Individuals larger than 160 mm in TL have been very rarely observed; for example, in March (164 mm) and in June (222 mm). As the sexual maturity of the species is attained after two years[17], the individuals occurring in the nearshore zone of Doigahama corresponds to the postlarval and juvenile stages. Mysid shrimps were the major food item in the smaller individuals below 10-100 mm in TL and they then eat larval and juvenile fishes thereafter[18].

F: 15; 7.7-146.3 mm; April 1998, May 1996, 1997, 1998, June 1994, 1996, 1998, September 1998, October 1996; D, N. C: 446; 11.8-222.0 mm; March 1999, April 1998, 1999, May 1997, 1998, 1999, 2000, June 1997, 1998, 1999, 2000, July 1998, 1999, 2000, September 1997, 1998, 2000, October 1996, 1997, 1998, 1999, November 1996, 1997, 1998, 2000, December 1997, 1998; D, N; R.

Tarphops oligolepis (Bleeker)

ARAMEGAREI

Although the occurrence of the species was limited to a particular season from June to November and the catch of this fish was not very frequent, many individuals were obtained from the nearshore zone. Early juveniles of 20-30 mm in TL occurred in the nearshore zone in June, then they grew to 60-80 mm in TL by the end of the year (Fig. 10). As this dwarf species attains its maximum length at about under 100 mm in TL, the individuals occurred in the nearshore zone of Doigahama corresponded to the juvenile and adult stages and part of the individuals may recruit to the spawning population. It was uncertain, however, that actual spawning occurred in the surf zone.

F: 1 ; 62.5 mm; September 1998; D. C: 212; 26.9-100.2 mm; June 1998, July 1998, September 1996, 1997, 1998, October 1997, November 1997; D, N; R.

Family PLEURONECTIDAE

Kareius bicoloratus (Basilewsky)

ISHIGAREI

C: 10; 66.4-123.3 mm; April 1999, May 1997, 1998, June 1997, 1998, July 1998, 2000; D, N; S.

Family SAMARIDAE

Samariscus latus Matsubara and Takamuki

TSUMARITSUKINOWAGAREI

F: 1 ; 5.0 mm; October 1998; N; S.

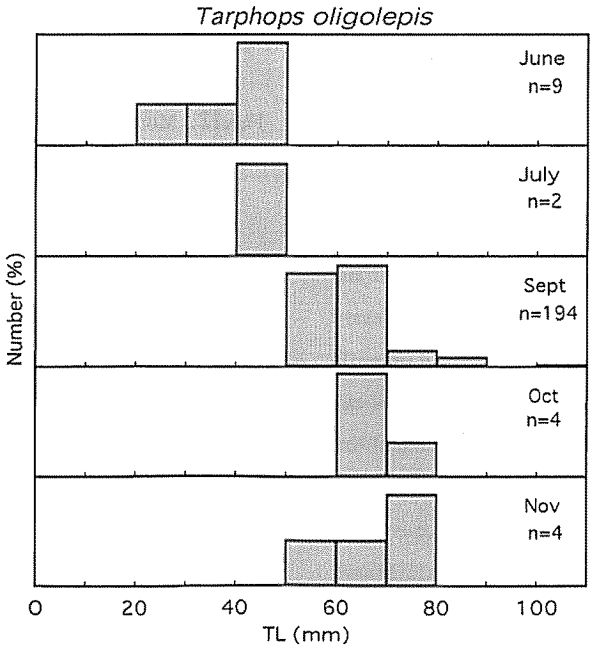

Fig.10. Monthly changes in the total length frequency distribution of *Tarphops oligolepis*. Each monthly frequency distribution is based on the data from the entire research period.

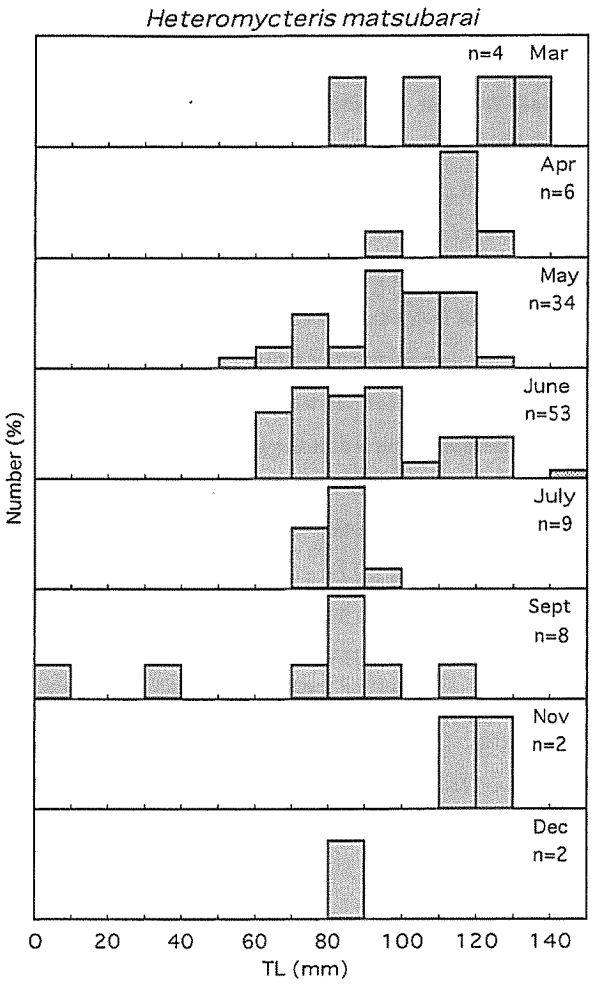

Fig.11. Monthly changes in the total length frequency distribution of *Heteromycteris matsubarai*. Each monthly frequency distribution is based on the data from the entire research period.

Family SOLEIDAE

Heteromycteris japonica (Temminck and Schlegel)

SASA-USHINOSHITA

Although the occurrence of the species was from March to December, most appearances were limited to May to September (Fig. 11). Most individuals were larger than 50 mm in TL except for a limited number of postlarvae and early juveniles in September, and corresponded to the juvenile and adult stages. According to the known growth of the species[19], age 0 - 3 fish were present in the nearshore zone. The major food items were mysid shrimps throughout the entire length range except for the very small ones[18].

F: 1 ; 4.6 mm; September 1998; N. C: 117; -142.4 mm; March 1999, April 1997, 1998, 1999, 2000, May 1997, 1998, 1999, 2000, June 1997, 1998, 1999, 2000, July 1998, 1999, September 1997, 1998, November 2000, December 1998; D, N; R.

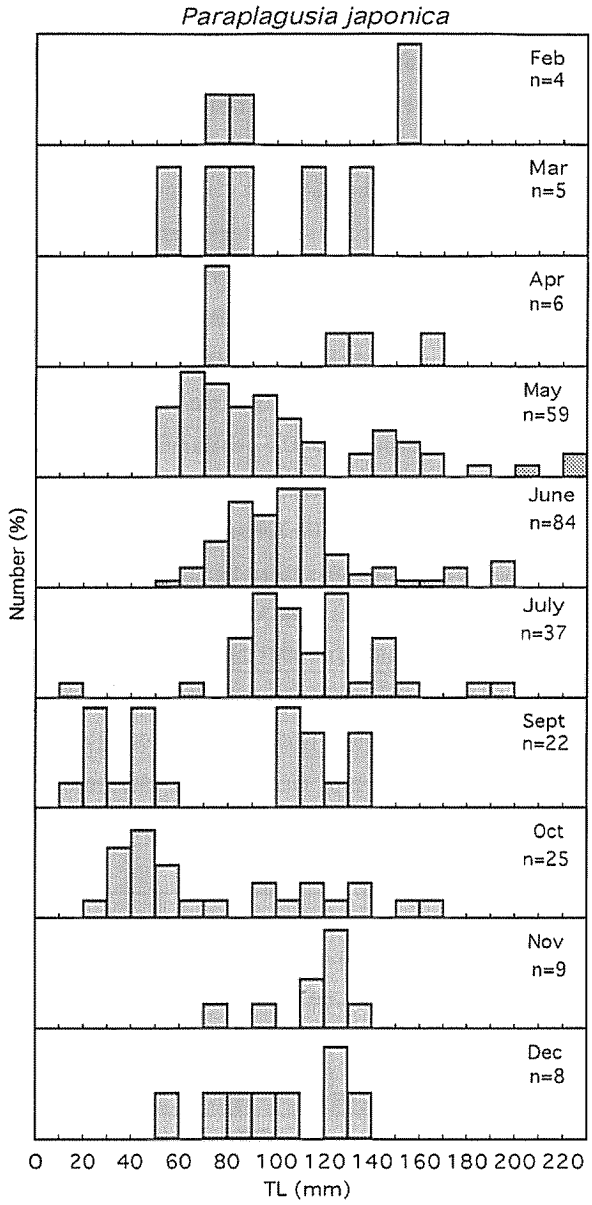

Fig.12. Monthly changes in the total length frequency distribution of *Paraplagusia japonica*. Each monthly frequency distribution is based on the data from the entire research period.

Family CYNOGLOSSIDAE

Paraplagusia japonica (Temminck and Schlegel)

KURO-USHINOSHITA

This was one of typical resident species in the nearshore zone and occurs from February to December (Fig. 12). Early juveniles occurred in July to October, they reached 80-100 mm in TL by the end of the year and 120-140 mm in TL by the end of the next year. Individuals larger than 160 mm in TL corresponding to two years old or more have been collected to some extent, although most of the individuals were smaller than 160 mm in TL. According to the

known growth of the species[19] age 0 - 2 fish were present in the nearshore zone. Mysid shrimps were the major food item in the individuals smaller than about 150 mm in TL and snails thereafter [18].

F: 9 ; 19.9-138.0 mm; May 1996, June 1996, 1997, 1998, July 1998, September 1997; D, N. C: 250; 18.6-223.4 mm; February 1997, 1999, 2000, March 1999, April 1998, 1999, 2000, May 1997, 1998, 1999, 2000, June 1997, 1998, 1999, 2000, July 1998, 1999, 2000, September 1996, 1997, 1998, 2000, October 1996, 1997, 1999, November 1996, 1999, 2000, December 1997, 1998, 1999; D, N; R.

Order TETRAODONTIFORMES

Family MONACANTHIDAE

Rudarius ercodes Jordan and Fowler

AMIMEHAGI

F: 9 ; 4.3-13.6 mm; June 1998, September 1996, October 1999; N. C: 2 ; 15.6-17.8 mm; October 1999; N; S.

Stephanolepis cirrhifer (Temminck and Schlegel)

KAWAHAGI

F: 3 ; 2.4-8.6 mm; June 1995, 1997; D; S.

Family TETRAODONTIDAE

Takifugu snyderi (Abe)

SHOSAIFUGU

C: 1 ; 44.2 mm; September 1996; N; S.

Takifugu porphyreus (Temminck and Schlegel)

MAFUGU

C: 1 ; 123.3 mm; September 1996; D; S.

Takifugu niphobles (Jordan and Snyder)

KUSAFUGU

This was a typical nearshore zone resident and occurred throughout the year (Fig. 13) and in every environmental condition even in the relatively harsh wave conditions. Early juveniles were collected in the nearshore zone from May to September. Although this species is known to spawn on the swash zone of the shingle shore, the spawning activity at Doigahama has not been recorded.

F: 126; 1.9-97.5 mm; May 1994, 1996, 1997, June 1994, 1996, 1997, 1998, July 1994, 1998, September 1996, 1998, October 1996, 1998; D, N. C: 1053; 12.2-174.4 mm; January 1999, February 1997, 1998, 1999, 2000, March 1999, April 1997, 1998, 1999, 2000, May 1997, 1998, 1999, 2000, June 1997, 1998, 1999, 2000, July 1998, 1999, 2000, September 1996, 1997, 1998, 2000, October 1996, 1997, 1998, 1999, November 1996, 1998, 2000, December 1996, 1998; D, N; R.

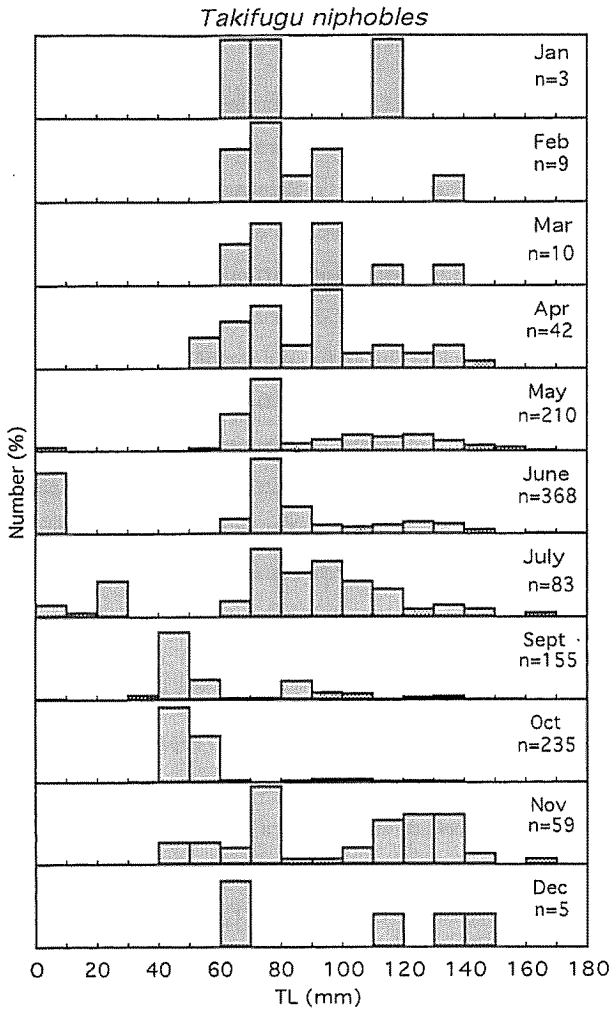

Fig. 13. Monthly changes in the total length frequency distribution of *Takifugu niphobles*. Each monthly frequency distribution is based on the data from the entire research period.

Takifugu reticularis (Tien, Chen and Wang)

AMIMEFUGU

C: 1 ; 138.0 mm; September 1997; N; S.

UNIDENTIFIED

F: 80; 3.0-14.0 mm. C: 6 ; 13.4-45.5 mm.

4 Discussion

These species that occurred in the surf zone at Doigahama could be classified into several categories depending on different biological aspects. Brown and McLachlan[7] mentioned four different groupings depending on the developmental stage, temporal association to the surf zone, food habit, and major habitat. Kinoshita[4] proposed a categorization based on the space and temporal association for the larvae and early juveniles. On the other hand, Suda et al.[10] tried to divide the several major surf zone fishes into five categories based on the combination of the developmental stage and adult habitat. Table 1 summarizes the developmental stage that occurred in the surf zone, temporal association, and major adult habitats for each species collected in the present study.

Although over 100 species are present in the nearshore zone, only six species (5 %; *Mugil cephalus cephalus*, *Lateolabrax latus*, *Sillago japonica*, *Paralichthys olivaceus*, *Paraplagusia japonica*, and *Takifugu niphobles*) are considered as the nearshore zone residents and 17 species (15 %) as seasonal migrants. Here the term resident means the fish species staying in the nearshore zone almost throughout the year with frequent occurrence during this period, and seasonal migrants are the species that occur during only a limited season or month(s). More than 80 species (80 %) are strays which occasionally come into the nearshore zone from other habitats due to either biological events (feeding, escapement from predators, etc.) or physical causes (wave, current, tide, etc.). The mention by Brown and McLachlan [7] that 1 to 5 species are the true residents in the surf zone has also been confirmed at Doigahama.

The occurrence of a variety of fishes possessing a strong association to a rocky environment may be caused by the geographical characteristics of Doigahama which is a relatively small scale beach situated among rocky shores (i.e., pocket beach). These fish move to innate habitats after their particular developmental stage or season and vanish from the surf zone. This implies that the sandy shore is an open habitat and its ichthyofauna there is affected by the adjacent or nearby environment.

When one considers the utilization of the nearshore zone as a habitat for fish, particular attention should be paid to both the residents and seasonal migrants. How these residents and seasonal migrants utilize the nearshore zone is of special concern for the value of the nearshore zone as their habitats. Several studies have already suggested its utilization as a feeding place and/or shelter from predators[20]. In Doigahama, several residents and seasonal migrants such as *Lateolabrax latus*, *Sillago japonica* (Suda unpubl.), *Paralichthys olivaceus*, *Paraplagusia japonica*, and *Heteromycteris japonica*[18] have been suggested to utilize the surf zone as a feeding place based on the feeding habit analyses.

Although the general view of the ichthyofauna and also part of the value of the nearshore zone as a habitat are clarified in the present study, the situations at other beaches with different morphodynamic states and other species are still unknown. Many more studies are necessary along these lines before the fish community structures of the nearshore zone can be appreciated.

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中間型砂浜海岸，土井ヶ浜のnearshore zoneにみられる魚類相

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中間型で干潮台またはリッジ/ラネルが出現するモルフォダイナミックス状態を示す山口県豊北町土井ヶ浜のnearshore zoneにおける魚類相を明らかにした．大きさと目合いが異なる2種類の調査用地曳き網を用い，昼夜，潮汐を通して採集を行った．1994年5月から2000年11月までの調査期間中に，62科112種以上，20,401個体の魚類が採集された．採集された魚類の発育段階は仔魚期から成魚期に亘り，ボラ，ヒラスズキ，シロギス，ヒラメ，クロウシノシタ，クサフグは土井ヶ浜のnearshore zoneの居住者種であると考えられた．