FISHERIES SCIENCE 2008; **74**: 285–292

Fish fauna associated with drifting sea weeds in the Chikuzen Sea, Northern Kyushu, Japan

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ABSTRACT: From 2002 to 2006, the fish fauna associated with sea weeds drifting in the Chikuzen Sea, northern Kyushu, Japan, was examined. The total numbers of species and individuals collected were 51 and 5475, respectively. The five dominant species, accounting for approximately 80% of the total individuals, were *Rudarius ercodes*, *Stephanolepis cirrhifer*, *Petroscirtes breviceps*, *Sebastes thompsoni* and *Paramonacanthus japonicus*. The number of species and individuals increased significantly with the increase in water temperature, reaching maxima during early summer and autumn, respectively. Combining the present and previous data (~50 years ago), the appearance patterns of the fishes associated with drifting sea weed were classified into the following four types: (i) long periods (continuously for 3 months or more) and autumn (LA); (ii) spring (SP); (iii) summer (SU); and (iv) rare (R). In more than half of the species, there were no changes in the appearance patterns between the present and previous studies. However, in the present study, the appearance patterns of several species changed from LA to R (*Oplegnathus punctatus* and *Kyphosus cinerascens*) and from R to LA and SU (*Abudefduf vaigiensis* and *Hyperoglyphe japonica*, respectively).

KEY WORDS: appearance patterns, drifting sea weeds, fish fauna, juveniles, young fish.

INTRODUCTION

Sargassacean sea weeds that have been broken or detached by strong waves often drift on the surface of the sea. The drifting sea weeds are used as spawning substrates by *Cololabis saira*, *Hyporhamphus sajori* and members of the family Exocoetidae.[1–5] In addition, larvae, juveniles and young fish belonging to more than 100 fish species are known to accompany such drifting sea weeds and use them for hiding or to migrate. Therefore, characteristic fish communities are found associated with drifting sea weeds.[1,5–7]

These fish communities have been investigated in several shallow waters such as northern Kyushu,[8,9] Sado Strait,[10] the west Pacific Ocean,[11] Seto Inland Sea,[12,13] Tohoku section[14–16] and Shimane Prefecture.[17,18] In some of these areas, seasonal changes in the fish species composition,[8–10,12] and seaweed species composition and abundance[19–21] have been reported. However, there are no studies that have reported temporal changes in the fish fauna associated with drifting sea weeds.

In this study, the fishes inhabiting the underside of drifting sea weeds were collected from the Chikuzen Sea over 4 years in order to investigate the seasonal changes in drifting seaweed communities. We also attempted to compare the fish fauna reported in this study with those reported in previous studies conducted between 1957 and 1959.[8,9]

MATERIALS AND METHODS

The sampling methods used in this study and previous studies[8,9] are summarized in Table 1. In this study, samples were collected from the Chikuzen Sea, northern Kyushu, Japan (Fig. 1) for a total of 32 months from July 2002 to November 2002, from April 2003 to March 2004, from June 2004 to July 2004, and from March 2005 to March 2006. The location of the study area, frequencies (1.5 times per month) and periods (3–5 h daily in the daytime) of sampling in this study were identical to

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Received 25 December 2006. Accepted 15 October 2007.

doi:10.1111/j.1444-2906.2008.01523.x

Table 1 Comparison of sampling methods used in the present study and previous studies[8,9]

	Uchida and Shoujima[8]	Shoujima and Ueki[9]	Present study
Dates	March 1957–March 1958 (13 months)	April 1958–March 1959 (12 months)	July 2002–March 2006 (32 months)
Study area	Triangular area including the Tsuyazaki, Ainoshima, and Chikuzen Oshima islands	Slightly more extensive than area studied by Uchida and Shoujima[8]	Identical to area studied by Uchida and Shoujima[8]
Time	3–5 h in the daytime	3–5 h in the daytime 5–10 h in the nighttime	3–5 h in the daytime
Frequency (times per month)	Daytime, 1.7	Daytime, 1.2 †Nighttime, 1.6	Daytime, 1.5
Net	Landing net and scooping net	Landing net and scooping net	Landing net

†Nighttime collection data were excluded when comparing three data sets.

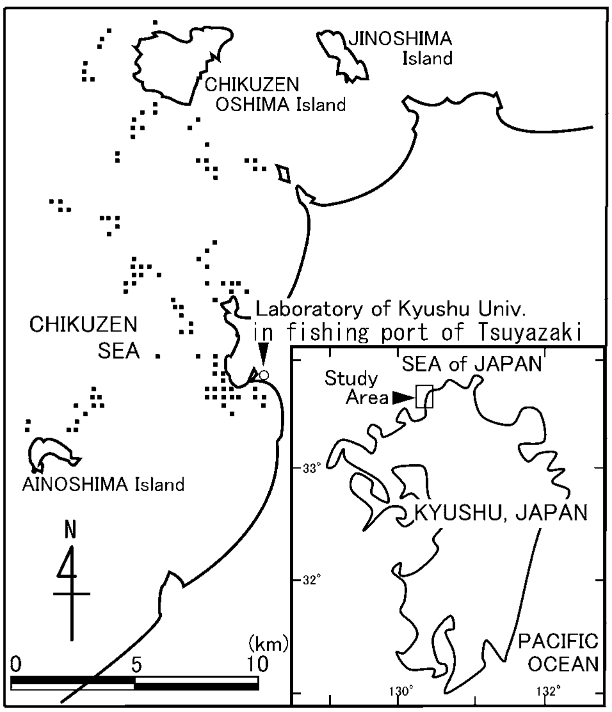

Fig. 1 Sampling sites. Sampling was conducted from 2002 to 2006 to observe the fish species associated with the drifting sea weeds in the Chikuzen Sea, northern Kyushu, Japan.

those in previous studies,[8,9] except for the presence of nighttime sampling in one of the previous studies.[9]

In the study area, samplings were made using R/V Isoshigi (2.2 t, 33.1 kW) belonging to the Laboratory of Aquatic Field Science, Kyushu University. When drifting sea weeds were found, fishes were collected along with the sea weeds by using a landing net (diameter 50 cm, depth 60 cm and mesh size 0.7 mm). When driftwood or large amounts of drifting sea weeds were present, we used two landing nets for a short period to collect the fishes to prevent escape. To avoid frightening the fish, we stopped the boat 10–20 m away from the drifting sea weeds and waited until the wind carried the boat near the drifting collections. The drifting sea weeds were collected by minimal net swinging. After fixing in 10% formalin on the boat, the collected fish were then transported to the laboratory and identified using pictorial books.[19–21] Each collection site was recorded using a GPS (Furuno Electric Co., Nishinomiya Japan), and the water depth and temperature were measured using a W-22XD meter (Horiba, Kyoto, Japan).

The fish fauna data were analyzed by cluster analysis (Ward method). The presence/absence of each fish was used as the parameter and represented as 1/0, respectively; cluster analysis was conducted based on this parameter for each fish species in each month in this study area. The daytime data of fish species reported in previous studies[8,9] (Table 1) were also analyzed and compared with the present data excluding the nighttime sampling data.[9]

RESULTS AND DISCUSSION

Fish fauna and dominant fishes associated with drifting sea weeds

The juvenile and young fishes collected along with the drifting sea weeds in this study are listed in Table 2. The total number of species and individuals collected were 51 and 5475, respectively, Individuals of all species, except *Histrio histrio* and *Lophiomus litulon*, were in the juvenile and young stages. The five dominant species were *Rudarius ercodes* (28.9% of individuals), *Stephanolepis cirrhifer* (21.4%), *Petroscirtes breviceps* (18.2%), *S. thompsoni* (9.0%), and *Paramonacanthus japonicus* (3.1%); these accounted for approximately 80% of the total number of individuals. *Rudarius ercodes*

Table 2 List of fish species, appearance periods, size range, and number of individual fishes collected around the drifting sea weeds from 2002 to 2006 in Chikuzen Sea, northern Kyushu, Japan

Species	Appearance periods	Size range (mm TL)	Number of individuals	Previous studies†
Plotosus lineatus	–	–	0	Apr–May
Lophius litulon	May	eggs	eggs	–
Histrio histrio	Jun–Aug	57.0–132.0	12	Jun–Jul, Oct
Mugil cephalus cephalus	May	25.0–36.1	57	Jul
Cyoselurus poecilopterus	Jun	9.2	1	–
Cypselurus heterurus doederleini	Jun	18.3–42.3	6	–
Cypselurus hiraii	Jun–Jul	9.0–17.5	43	–
Cypselurus starksi	Jun–Jul	14.2–37.0	11	Jul
Hirundichthys oxycephalus	Jun, Aug	10.8–26.5	3	–
Hyporhamophus sajori	Jun	11.0–19.0	4	–
Ablennes hians	Jun–Sep	28.7–36.5	12	Jul
Strongylura anastomella	May, Jul	23.2–24.5	2	–
Tylosurus crocodilus crocodilus	Jun–Jul	18.5–22.0	2	Jul
Syngnathus schlegeli	Year round	45.2–90.5	58	Feb–Mar, May, Jul–Sep
Trachyrhamphus bicoarctatus	Jun	53.2–60.0	2	–
Trachyrhamphus longirostris	Jul	13.0	1	–
Urocampus nanus	Jul	46.0–82.0	1	Jul
Hippocampus kuda	Jul	60.0	1	–
Sebastes hubbsi	Nov, Jan	18.4–18.9	4	Oct
Sebastes inermis	Mar–May	16.0–50.0	124	Feb–May
Sebastes thompsoni	Apr–May	19.5–42.8	494	Feb–May‡
Sebastiscus marmoratus	–	–	0	Apr
Platycephalus sp.2	Jul	11.0	1	–
Hexagrammos agrammus	Mar–May	37.1–74.9	12	Feb–May
Scombrops boops	Oct	22.1	1	–
Coryphaena hippurus	Jun–Sep	21.2–45.7	10	–
Seriola dumerili	–	–	0	Jul
Seriola quinqueradiata	May–Jun	20.0–53.0	13	May–Jun
Trachurus japonicus	Aug	25.2–43.0	14	May
Lethrinus genivittatus	Sep	21.0–23.0	6	Jul
Pagrus major	Jun	11.3–11.5	2	Apr
Upeneus japonicus	Sep	17.2–19.0	3	Jul
Kyphosus cinerascens	Mar, Jun, Nov	22.2–46.5	4	Jul–Aug, Oct–Nov
Kyphosus vaigiensis	–	–	0	Jul
Microcanthus strigatus	Dec	17.7	1	Dec
Girella leonina	Dec	26.5	1	May–Jun, Dec–Feb‡
Girella punctata	Apr–Jul	15.2–26.5	152	May–Jun, Dec–Feb
Oplegnathus fasciatus	Jun–Aug	18.5–43.9	81	Jul–Oct
Oplegnathus punctatus	Jun	22.5–42.4	3	May–Jul, Oct–Nov
Hyperoglyphe japonica	Jun–Sep	100.3–142.0	11	Mar
Abudefduf vaigiensis	Jun–Dec	10.1–67.5	41	Mar, Jul–Aug, Oct, Dec
Chromis notata notata	Jul, Sep	8.5–12.4	51	–
Pomacentrus coelestis	–	–	0	Jul
Pholis nebulosa	Mar–Jul	50.1–93.5	48	Feb–Jun, Oct, Dec
Entomacrodus stellifer stellifer	Nov–Dec	18.0–20.3	19	Oct
Petroscirtes breviceps	Jun–Jan	8.0–71.0	995	Apr, Jun–Dec
Plablennius yatabei	Jun–Jul, Oct–Nov	16.6–19.3	116	Jul
Siganus fuscescens	Jul–Sep	24.8–29.8	12	Jul–Aug
Canthiadermis maculata	Sep	40.0	1	Aug
Aluterus monoceros	–	–	0	Aug
Aluterus scriptus	Jun	123.5	1	Jul
Paramonacanthus japonicus	Jun–Oct	9.0–25.8	168	Jul–Nov
Rudarius ercodes	Jul–Dec	5.4–32.6	1585	Jun–Dec
Stephanolepis cirrhifer	Jun–Dec	6.0–48.0	1172	Jun–Dec
Thamnaconus modestus	Jun	10.4–60.5	106	Jun
Lagoephalus wheeleri	Aug	6.0–10.5	4	–
Takihugu pardalis	May	10.0–12.0	3	Jul

Orders and families are arranged according to Nelson's[22] classification; scientific names are according to Nakabo.[21]
†Uchida and Shoujima[8] and Shoujima and Ueki.[9]
‡*Sebastes inermis* and *Sebastes thompsoni* or *Girella leonina* and *Girella punctata* were identified in the present study by using pictorial books;[20] previous studies did not identify these two species.[8,9]

appeared from July to December, *S. cirrhifer* from June to December, *P. breviceps* from June to January, *S. thompsoni* from April to May, and *P. japonicus* from June to October. The total lengths of these five fish species ranged 5.4–32.6 mm, 6.0–48.0 mm, 8.0–71.0 mm, 19.5–42.8 mm and 9.0–25.8 mm, respectively.

Four (*R. ercodes*, *S. cirrhifer*, *P. breviceps* and *P. japonicus*) of the five species are common in the shore reef around the study area;[23,24] however, *S. thompsoni* was quite rare in the shore reef around the study area.[23,24] *Stephanolepis thompsoni* migrates for long distances in association with the drifting sea weeds.[25] Therefore, most *S. thompsoni* that appears in the Chikuzen Sea are estimated to migrate further north of the Sea of Japan along with drifting sea weeds.[5,15,20,25]

Among the collected 51 species, 38 (74.5%) were common along the coast of shore reefs.[23,24] The other 13 species (25.5%) were migrating species (*S. thompsoni*),[5,15,20,25] pelagic species (*Coryphaena hippurus, Canthiadermis maculata*, *Aluterus scriptus* and five exocoetidaean species),[1,4,19–21] deep sea species (*Hyperoglyphe japonica* and *Lagoephalus wheeleri*)[1,5,19–21] or species endemic to drifting sea weeds.[1,19–21] These coastal fishes are considered to adopt the 'raft strategy', and they use drifting sea weeds in the larval, juvenile and young fish stages to expand their distribution regions.[1]

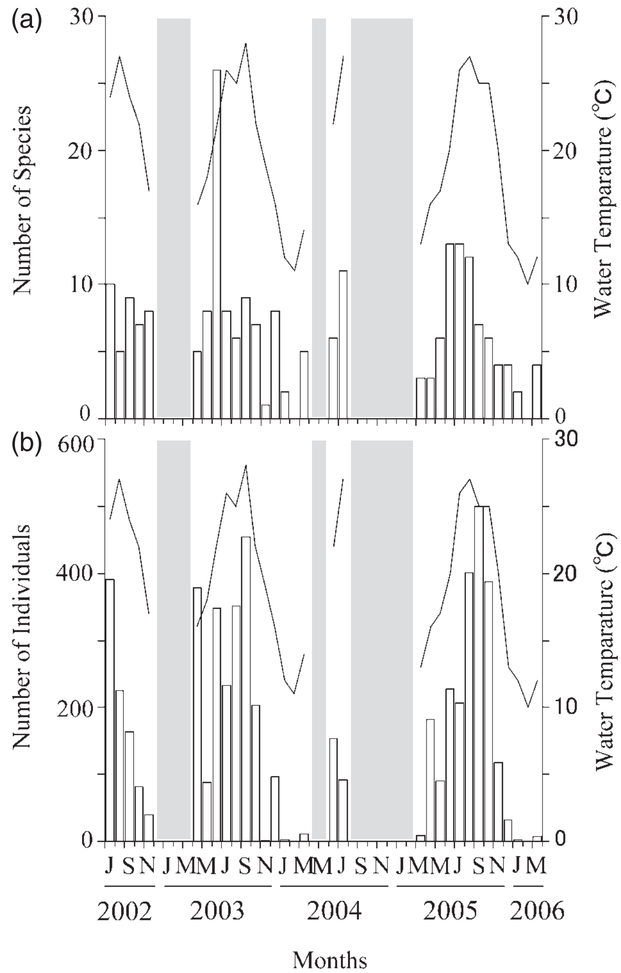

Fig. 2 Seasonal changes in (a) the number of species and water temperature, and (b) number of individuals and water temperature observed with regard to the fish fauna associated with the drifting sea weeds in Chikuzen Sea. Shaded areas, no data.

Seasonal changes in number of species and individuals

In each fiscal year, the maximum number of fish species was collected during early summer: 10 species were recorded in July 2002, 26 in June 2003, 11 in June 2004, and 13 in June and July 2005 (Fig. 2a). On the contrary, the maximum numbers of individuals were recorded during summer or autumn, i.e. 391 individuals in July 2002, 454 individuals in September 2003 and 500 individuals in September 2005 (Fig. 2b). However, in September 2002, when assemblages of drifting sea weeds were not easily found because of high waves caused by a typhoon, common members such as *R. ercodes* and *S. cirrhifer* were obtained in small numbers. Samplings were also insufficient because of bad weather in November 2003; even common members such as *P. breviceps* were obtained only in small numbers. Numbers of species and individuals were at their minimum during the winters of 2004 and 2006. However, numbers were not clear due to insufficient samplings because of bad weather in the winters of 2003 and 2005.

In this study, the numbers of species and individuals in the fish communities associated with drifting sea weeds were the highest in the summer and autumn, respectively; this pattern was also reported in previous studies.[8–12] We take the following views on the differences in the peaks between the number of species and the number of individuals. The number of species is known to be related to the volume of the drifting sea weeds.[1,5,8] Most sea weed is known to drift considerably from late spring to early summer.[1,12,26–28] In addition, the fish species associated with the drifting sea weeds in late spring to early summer are known to spawn between winter and early spring.[12,20] This might be the reason why the number of such fish species becomes the largest in the early summer.

In contrast, four dominant species (*R. ercodes*, *S. cirrhifer*, *P. breviceps* and *P. japonicus*), accounting for 71.6% of the total number of individuals, appeared in autumn when the number of collected fish species was lower than that in summer.[5,8,9] Since these species spawn during summer,[19,20] their juvenile and young fishes appear in autumn. In addition, these species are known to frequently appear as reef fishes in the North-western Kyushu coast.[23,24,29,30] This might be the reason why the number of collected individuals was the largest in autumn.

The water temperature was the highest in the period from August to September and lowest in February (Fig. 2). In addition, the abovementioned values (the number of collected fish species and individuals that exhibited a positive correlation with water temperature (Kendall rank correlation coefficient, number of species $\tau = 0.543$, $P < 0.01$, $n = 32$; number of individuals $\tau = 0.625$, $P < 0.01$, $n = 32$). These positive correlations corresponded to the tendencies observed in rocky reef fish communities in the Chikuzen Sea.[24] Therefore, the numbers of collected fish species and individuals associated with the drifting sea weeds seem to depend on the seasonal changes in water temperature as found in the reef fish communities.

Comparisons of fishes obtained in present and previous studies based on cluster analyses

Fishes collected around drifting sea weeds in previous[8,9] and the present study were classified into the following four types by cluster analysis based on the presence or absence of data for each month (Fig. 3).

1. Long period including autumn appearance (LA). These fishes appeared associated with the drifting sea weeds for long periods (continuously for 3 months or more), including autumn (throughout or for some days in September, October and November). Typical fishes were *R. ercodes*, *S. cirrhifer* and *P. breviceps*.
2. Spring appearance (SP). These fishes appeared associated with the drifting sea weeds throughout spring, i.e. from March to June. Typical fishes were *Sebastes* spp., *Hexagrammos agrammus* and *Pholis nebulosa*.
3. Summer appearance (SU). These fishes appeared associated with the drifting sea weeds throughout summer, i.e. from June to August. Typical fishes were *Oplegnathus fasciatus*, *Siganus fuscescens* and *Canthidermis maculata*.
4. Rare appearance (R). These fishes were rarely present; their appearance was limited to once during this study period. Typical fishes were *Microcanthus strigatus* and *Tylosurus crocodilus crocodilus*.

More than half of the total species collected in the previous and present studies had similar appearance patterns and were classified into the same types (Fig. 3); however, several fishes were also classified into different types. The following changes in the patterns were observed between the previous[8,9] and the present studies.

Change from LA to R: *Oplegnathus punctatus* and *Kyphosus cinerascens*. In previous studies,[8,9] these two species were reported to be the typical fishes that accompanied with drifting sea weeds;[1,5,8,9] however, they rarely appeared in this study.

Change from SP to R: *Pagrus major*. By using cluster analysis in this study, the previous appearance pattern of this species was classified as the SP type. Although the behavior of this species in association with the drifting sea weeds was once doubted,[5] rare appearance was confirmed in the present study.

Change from R to LA: *Abudefduf vaigiensis*, *Plablennius yatabei* and *Sebastes hubbsi*. The appearance periods for these fishes in the present study were longer than those in the past.[8,9]

Changes from R to SU: *Histrio histrio*, *Trachurus japonicus* and *Hyperoglyphe japonica*. The appearance periods for these fishes in the present study were longer than those in the past.[8,9] In particular, an increase in *H. japonica* has been reported in several parts of Japan in recent years.[18,31]

Change from SP to LA: *Syngnathus schlegeli*. This was the most frequently collected species in the present study.

Such extension or shortening of appearance periods might have occurred because of environmental changes or overfishing. However, further studies are needed to clarify the reason.

In the Chikuzen Sea, the water temperature has been rising by approximately 0.1°C every year for 25 years since the 1980s, and the proportion of tropical fish species in the fish fauna has increased.[31–33] However, there were no remarkable differences observed in the fish communities associated with the drifting sea weeds in this area between the previous[8,9] and present studies. In the fish communities associated with the drifting sea weeds in the studied area, two reasons are possible for the lack of changes in the fish communities despite the increase in water temperature. One is unchanged spawning seasons of each species,[1,5,19,20] and the other is the unchanged volume and occurrence season of the drifting sea weeds.[1,5,8,9,26–28]

In general, abiotic environmental factors (for example, water temperature) influence the distributions of each species.[24,34–40] In the case of tropical and subtropical fish species, their distributions

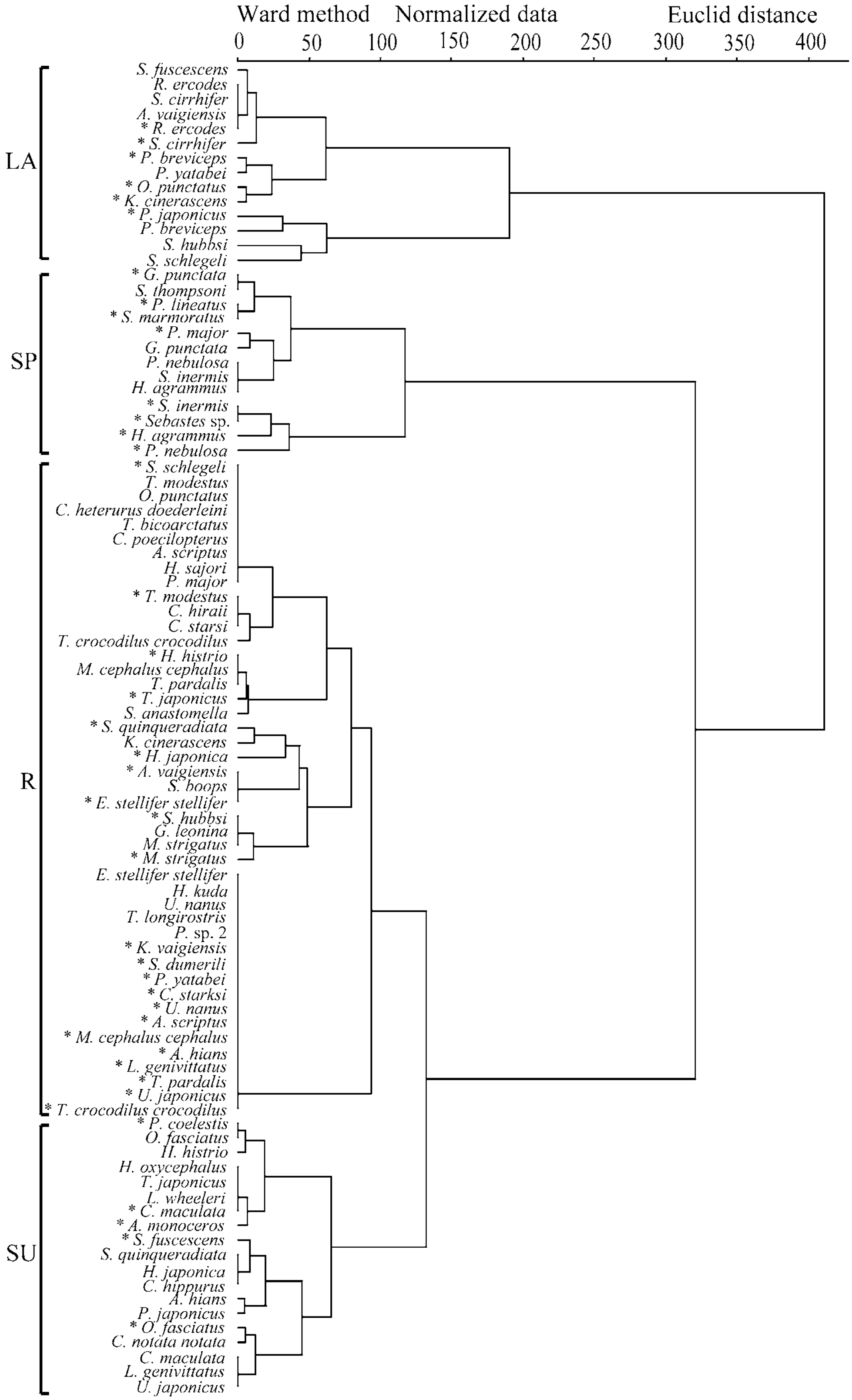

Fig. 3 Seasonal patterns of the fishes collected around drifting sea weeds classified according to cluster analysis based on the presence/absence of data reported in the previous[8,9] (*species name) and present studies (species name). LA, fishes appearing for long periods and during autumn; SP, fishes appearing during spring; SU, fishes appearing during summer; R, fishes rarely appearing.

may extend toward the north with the rise in water temperature caused by reasons such as global warming.[31,34,39,40] Some reports mention that the number of tropical and subtropical species has increased with the increasing water temperature in recent years.[24,31,34,40] In this study, the fish communities associated with drifting sea weeds indicated no remarkable changes with increase in water temperature. However, in the detailed investigation of appearance types, several fish species such as *A. vaigiensis* and *H. japonica* that extended their appearance period were tropical and subtropical fishes.[18,31,34,40] The juvenile and young fish communities found associated with the sea weeds in this area might also begin to change their appearance patterns gradually.

ACKNOWLEDGMENTS

We thank Y Shichita and M Tsujigawa, who assisted collecting the drifting sea weeds and S Nishida of Kyushu University, for cooperating with us during this study. We also thank Dr D Fujita, Tokyo University of Marine Science and Technology for valuable comments on this manuscript. This study complied with the current laws of Japan.

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