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Drifting seaweed and associated ichthyofauna: Floating nursery in the Tohoku waters*

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Abstract: Drifting seaweed and associated ichthyofauna were sampled in the Tohoku Area, northwest Pacific, in spring of 1988, 1989 and 1990, to analyse the structure of these communities and ecological relationships of the dominant fish species. Results as a whole showed: 1) The abundance of drifting seaweed in the Tohoku Area peaked in May-June and decreased in July. The young and fresh algae were dominated by *Sargassum hornerii*, and seemed to drift mainly from the nearest coast: Sendai Bay and its northern part. While starting drifting, they were almost defaunated and they reached the Kuroshio Extension where they were mixed and entangled with other seaweed-some from the southern part. 2) *Seriola quinqueladiata* was the dominant species of the associated fish community, and its escort was composed of *Thamnaconus modestus, Sebastes inermis, Hyperoglyphe japonica* and *Enedrias nebulosus*. *E. nebulosus*, which fed essentially on Gammarid crustaceans, was collected mainly in Sendai Bay; the other species, found in offshore water, were plankton feeder and did not exhibit any strong competition, indicating close cohabitation. 3) Juvenile *S. quinqueradiata* seemed to use drifting seaweed (along with the warm Kuroshio current) as a means of transportation during their migration from the southern spawning ground to northern Tohoku Area; but the most likely hypothesis, taking into consideration the number of rings counted on otoliths, might be a passive drift of eggs and larvae with the Kuroshio during a maximum of 30 days (effective period of survival), then juveniles might have encountered the Tohoku drifting seaweed and be associated with them since a period of about 10 days. Drifting seaweed-associated fish community was made of juveniles, like if it was a result of a regular flow of individuals passing into it and replenishing the stocks with juveniles, like a floating nursery, and they might have an influence on species recruitment.

1. Introduction.

The aggregations of pelagic fishes near or beneath drifting or moored objects at sea forms the basis of a number of commercial fisheries. "Floating Fish Shelter" is a fish shelter to collect fish such as skipjack, tuna, dolphin, etc. in offshore waters, and shad, mackerel, etc. in the coastal waters, taking advantage of the habit of pelagic fish to gather under floating objects drifting in surface waves. The former aims at forming a fishing ground to attract stationary demersal fish and thereby to increase fisheries catch, and at establishing itself as a place to conserve and rear fish (KOBAYASHI, 1989). This fishing method is the most popular in the sea area of Asia and Southeast Asia (HARDENBERG, 1950; SOEMARTO, 1960; GALEA, 1961; HUNTER and MITCHELL, 1967). Japanese poleand-line fisheries and American purse seine and live-bait fisheries take advantage of the association of yellowfin tuna (*Thunnus albacores* Bonnaterre), and oceanic skipjack (*Katsuwonus pelamis* Linnaeus) with algae, logs, and other flotsam (UDA, 1933; Mc NEELY, 1961). Moored rafts of bamboo or palm fronds are used to attract dolphin-fish (*Coryphaena hippurus* Linnaeus), in Japanese seine fisheries (KOJIMA, 1956). In addition to these commercially important species, many others of lesser or no commercial value are also encountered (HIROSAKI, 1960; KOJIMA, 1960; SENTA, 1962; ANRAKU and AZETA, 1965; GOODING and MAGNUSON, 1967; IDA *et*

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al., 1967; HUNTER and MITCHELL, 1968; MITCHELL and HUNTER, 1970; DOOLEY, 1972; IKEHARA, 1977; NAKATA *et al*., 1988; SANO, 1989; TSUKIDATE, 1989; SAFRAN and OMORI, 1990; SAFRAN, 1990b).

These aggregations are dominated initially by small juvenile fishes. The factors influencing those migrations and temporary concentrations have yet to be determined. Fishery studies tend to concentrate upon commercial adult populations, and knowledge of factors that influence the juvenile populations is often poor (WEINSTEIN, 1982; ALDERDICE, 1985). Recruitment to adult stocks depends on the events occuring during the juvenile growth period. Drifting or moored objects at sea ensure the permanence of populations, but at the same time, owing to their specificity, their limited area and the possible competition between species, they constitute a limitation, and likely a regulation mechanism for stocks. It is therefore clear that spatio-temporal variations, abundance fluctuations, and cohort successions of sampled populations inside these aggregations cannot be analysed for one target-species without taking into consideration the fluctuations of the other species. This reflects the realization that single-species population dynamic models are insufficient for fisheries management purposes. Multi-species interactions must be considered as well as the impact on stocks caused by fishing, etc. (SAFRAN, 1987b, 1990a).

Moreover, among the various floating objects on the sea surface, drifting seaweed are the most usual :the major species found around Japan are of the genus *Sargassum* and allied genera (YOSHIDA, 1963; OHNO, 1984). Although the Pacific Ocean Sargassum Complex has been studied in southern waters off Japan(UCHIDA and SHOJIMA,1958; HIROSAKI, 1960, 1965; SENTA, 1962, 1966; IDA *et al*., 1967; NAKATA *et al*., 1988), few description of the fish fauna associated with drifting seaweed has been made in the Tohoku Area (Northwest Pacific). The study presented here describes in this area the drifting seaweed and associated ichthyofauna, providing information on the fish community structure, and on the ecological inter- and intra-relation of the dominant species which compose this association.

Special attention is also given to a well known drifting seaweed-associated yellowtail *Seriola quinqueradiata* Temminck et Schlegel (ANRAKU and AZETA, 1967), and its escorts, in order to clarify the drift-associated mechanism and to emphasize the role of the drifting seaweed on the fish behavior.

This work is a part of a survey performed in the Tohoku waters and published in SAFRAN (1990b).

2. Materials and methods

Study area

Drifting seaweed are mainly distributed in coastal waters, their abundance reaching a peak in May–June and decreasing after August (YOSHIDA, 1963; OHNO, 1984). Thus, series of sampling were performed in late spring of 1988 and 1989, and in spring of 1990. In 1988, a first cruise, in Sendai Bay on R. V. "Suiko" was from June 6 to June 10 in the vicinity of a station 141°E, 38°N, a second, in the Kuroshio Extension (along the 38°N), was from Sendai Bay to 160°E, on R. V. "Waka Chiba Maru" from May 22 to June 10; and a third was carried out, in the northern part of the Tohoku Area, by T. S. "Hokusei Maru" from June 20 to July 4. In 1989, a first cruise was from May 25 to May 30 on R. V. "Tansei Maru", along the line shown in Fig. 1a ; a second, in the Kuroshio Extension, was from Sendai Bay to 140°E, on R. V. "Shin Dai To Maru" from June 5 to June 8 (Fig. 1b), a third, in Sendai Bay, was on June 24 in the vicinity of a station 141°E, 38°N, on R. V. "Suiko", and a fourth, also in Sendai Bay, was from July 6 to July 7 on R. V. "Shin Dai To Maru" (Fig. 1c). In 1990, a cruise in the Perturbed Area, along the 36°N and the 38°N, was from Sendai Bay to 150°E, on R. V. "Waka Take Maru" from May 12 to May 24.

Sampling method

Daily samples were collected using a net ca 7 m long with 2 mm mesh opening,

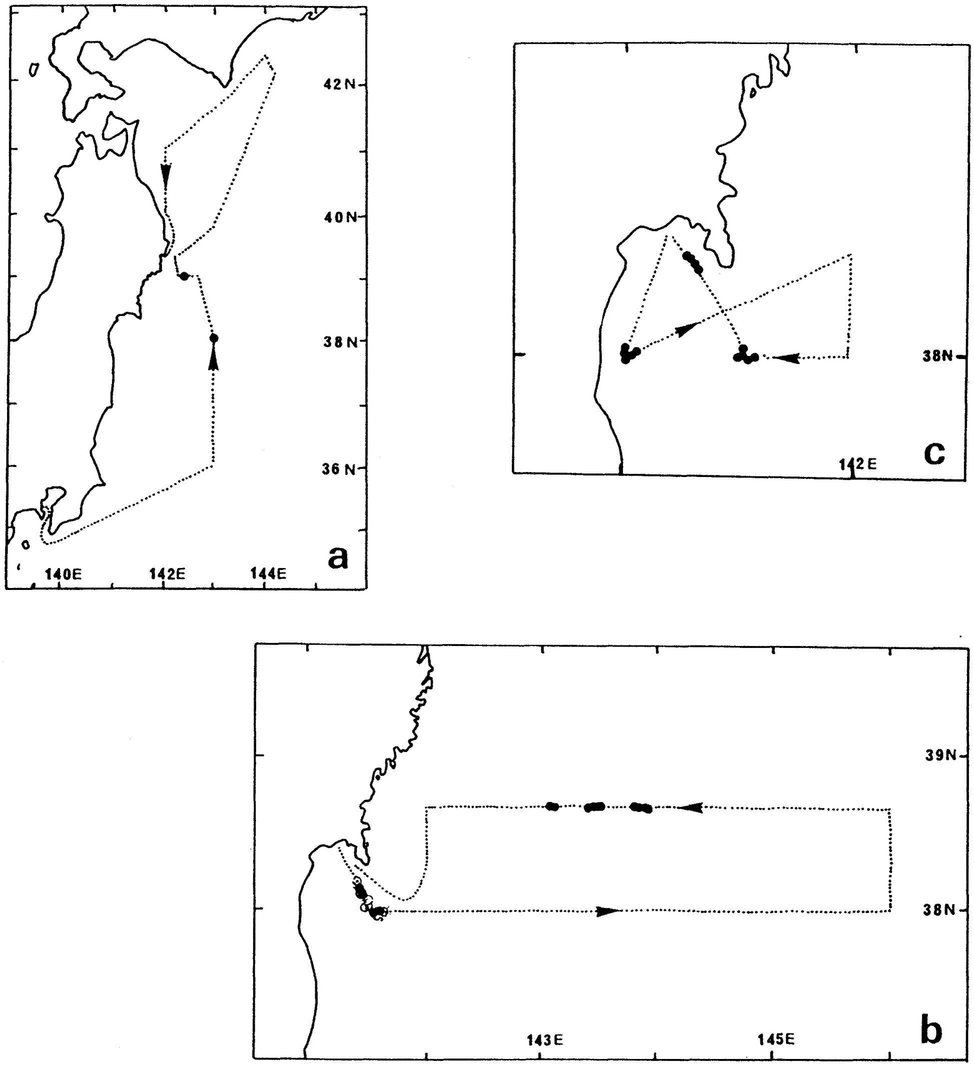

Fig. 1. Study area and sampling locations in 1989: overall location (a), the Perturbed Area along the Kuroshio Extension (b), and Sendai Bay (c). Dotted lines: the cruising routes; open circles: position of drifting seaweed; filled circles: sampling stations.

attached to a 2 m diameter mouth-ring. Two floats, fixed on the ring, allowed 2/3 of the mouth-ring to be immersed below the sea surface. A *Sargassum* patch that could be entirely caught was selected, when spotted on the sea surface, and sampled from the vessel's port side, at a speed of about 2 to 4 knots. Temperature and salinity were also recorded (in 1988). Though sampling errors were probably small, this method seemed to be unsuitable to collect the epiphytal fauna due to the turbulence of the water, the occurrence of eddies, and the inappropriate mesh size of the net. Algae samples were rinsed thoroughly in large tubs and the water strained through a sieve (<1 mm mesh opening). Organisms thus collected were preserved in 10% buffered formalin for later sorting and determination of stomach contents, in 1988. While in 1989, they were preserved in 10% alcoholic solution for later lecture of otoliths; and in 1990, they were frozen on board. The wet weight of seaweed was measured to the nearest 0.5 kg on a machete beam-balance, a portion of which was then preserved in buffered formalin for epibiotic analysis, and the remainder discarded. Fish standard lengths (SL) were measured to the nearest mm; the wet weight of each fish species was determined to the nearest g. Stomach contents analyses were conducted on preserved specimens of the dominant species to check a possible inter-and/or intra-specific competition phenomenon. The shortest distance to the shore from the location of each collection was measured to the nearest nautical mile to determine if the size, the growth or the number of fishes were related to the distance from the shore. Otoliths of *Seriola quinqueradiata* and some of *Tamnaconus* (*Navodon*) *modestus* (in 1989) were extracted to get a better idea of their age by observation of daily growth increments (CASSELMAN, 1983). Otoliths were washed and rinsed with a sodium hypochlorite solution, mounted on a glass microscope slide with a drop of nail varnish, and removed under a binocular microscope (Olympus, equipment from the Tohoku Regional Fisheries Research Laboratory), where growth rings were counted.

Data analysis

The haul composition was variable so the ecological diversity of the community was estimated by the Shannon Index (SHANNON and WEAVER, 1963), while Evenness was obtained by the Pielou Index (PIELOU, 1966). A good description of the specific diversity (H') of a sample is given by a representation of the distribution of individuals among species, which is the structure of a community as the arrangement in a definite pattern of organization and/or the aggregate of species of an entity in their relationships to each other (FRONTIER, 1985). Rank-Frequency Diagrams (RFDs) are used to model this distribution. The shape of the curve is generally irregular, smoothed curves are obtained by cumulating samples (following SAFRAN, 1987a and b). In this study, cumulative RFD were obtained by summing species by species; species are ranked after summing their abun dances over the set of samples, due to the weakness of the sampling strategy (SAFRAN, 1990a). Qualitative similarity was estimated by the Ochiai Index (OCHIAI, 1957), based on the presence/absence of species.

Numerical data were arranged in ecological categories, obtained from stomach analyses of the dominant species in the drifting sea weed-associated community. Thus study of niche relationships and the ecological role of an organism in a community, especially in regard to food consumption could be performed. The niche breadth of a species can be estimated by measuring the uniformity of the distribution of individuals of that species among the resource states (COLWELL and FUTUYMA, 1971):the measure of species niche breadth is the Shannon-Wiener formula for information and uncertainty (SHANNON and WEAVER, 1963). Niche overlap, as the joint use by two or more species of a resource, or resources, regardless of resource abundance (ZARET and RAND, 1971), was estimated using the overlap measure of MORISITA (1959) as modified by HORN (1966). Diet similarity was estimated by the Ochiai Index (OCHIAI, 1957), based on the presence/absence of prey.

3. Results

Drifting seaweed

Drifting seaweed were mainly found in the Perturbed Area along the Kuroshio Extension, where waters were mixed showing a thermic front. In 1988, no obvious relation was evident between the distance from shore and the seaweed wight: $r = -0.565$ (Fig. 2a). Nevertheless, the bulk of drifting algae found in Sendai Bay (mean value 24.21 ± 18.47 kg) were larger than those collected offshore along the Kuroshio Extension (mean value 9.42 ± 7.41 kg). Similarly, the same kind of results were noticed in 1989 with a lower correlation: $r = -0.133$ (Fig. 2b), with a larger bulk of drifting seaweed in Sendai Bay (mean value 20.17 ± 15.58 kg) than in the Kuroshio Extension (mean value 10.23 ± 14.92 kg) . In 1990 (Fig. 2c), drifting seaweed caught near the coast (ca 21 nautical miles) were found in cold water (15.4℃), bigger (21.14 ± 8.21kg) and without fauna, while offshore samples, eollected in warm

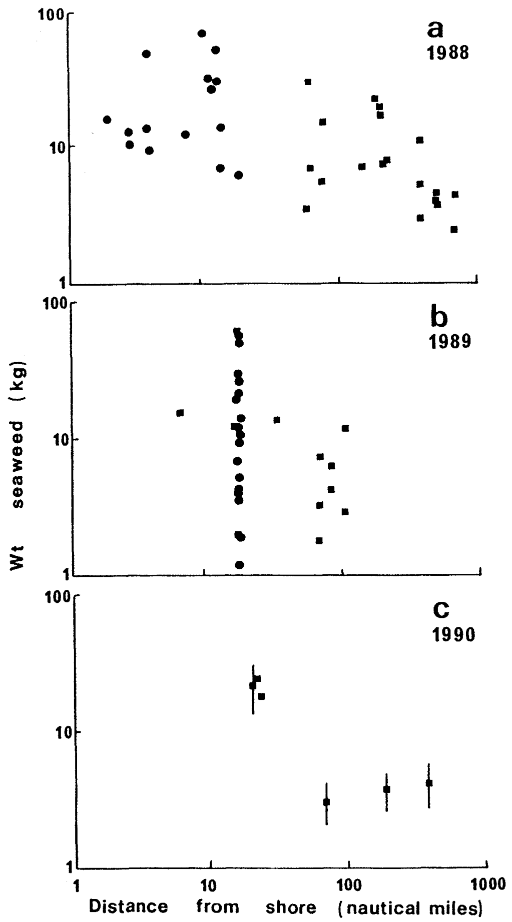

Fig. 2. Relationships between distance from shore and the weight of drifting seaweed in 1988 (a), 1989 (b), and 1990 (c). Filled circles: samples collected in Sendai Bay; filled squares: samples from the Kuroshio Extension.

water (17.26° ±0.52℃), were smaller (3.59 ±0.34 kg) with fauna (epiphytal fauna and fishes). The difference in the size of the offshore samples were not highly significant (3.11±1.13 kg at 70 miles, 3.79 ±0.92 kg at 190 miles, and 3.88±1.71 kg at 390 miles).

In 1988, 7 species were found in Sendai Bay and were dominated by *Sargassum hornerii* (Turner) C. Agardh. In the Perturbed Area, 14 species were collected and the dominant species was *S. hornerii*, while only 3 species were caught near Hokkaido. The results obtained showed *S. hornerii* as the dominant species among 20 collected (H' = 3.090, E = 0.715). *Sargassum patens* was found only offshore along the Kuroshio Extension, while *Coilodesme japonica* was caught exclusively off Hokkaido and always associated with *Cystoseira hakodatensis*; and *Sargassum confusum* and *Eisenia bicyclis* were sampled in Sendai Bay. In 1989, 5 species were found in the Perturbed Area, While 4 species were sampled in Sendai Bay. *S. hornerii* was the dominant species among 7

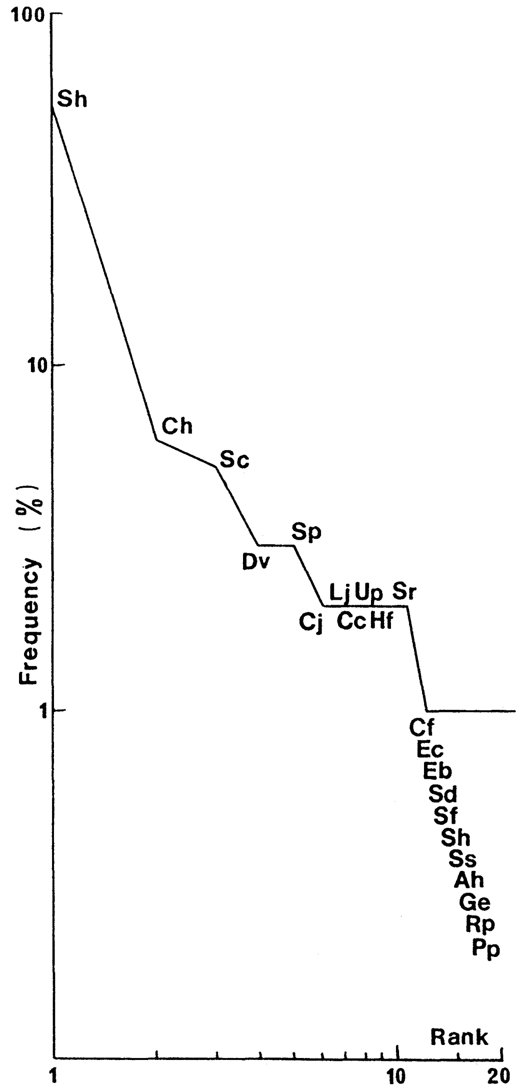

Fig. 3. Cumulative Rank-Frequency Diagram obtained for the drifting seaweed community in the Tohoku Area. Species abbreviations as in Appendix.

collected (H' = 1.634, E = 0.582). The 1990 samples were mainly *S. hornerii*. These results led to a cumulative RFD giving an overall picture of this drifting seaweed community in the Tohoku area (Fig. 3), which was made of 22 species (H' = 2.613, E = 0.586), and dominated by *S. hornerii*. The shape of the RFD showed a juvenile stage for the sampled aggregations of algae.

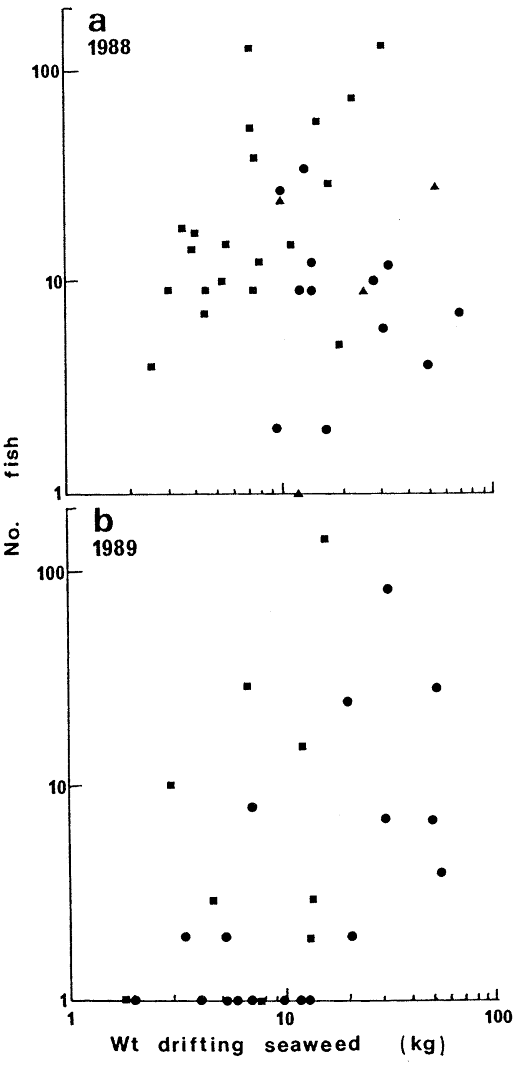

Fig. 4. Relationships between weight of drifting seaweed and number of fish gathering within in 1988 (a), and in 1989 (b). Filled circles: samples collected in Sendai Bay; filled squares: samples from the Kuroshio Extension; filled triangles: samples obtained at the outset of the cruise off Hokkaido.

Associated ichthyofauna

There was no obvious correlation between individual and species number of fishes, and/or seaweed weight, and hydrographic condition (but this last point is doubtful since most of the seaweed, where fish were found, were caught in similar hydrographic conditions and always in thermic fronts). Statistical analyses revealed a low correlation between the seaweed weight and number of fishes, the correlation coefficient was r = 0.557 with 30.8% due to the correlation and 69.2% residual, in 1988 (Fig. 4a). The correlation was lower in 1989: r = 0.248 (Fig. 4b); while there was no relation with the specific richness. Similarly, no obvious relation was evident between the distance from shore and the specific richness, while low correlations were found with the number of fishes with r = 0.443 in 1988, and r = −0.137 in 1989.

Considering the Tohoku Area as a geographical entity, as opposed to just the southern area, and grouping all samples, the cumulative RFD revealed a general condition for the drifting seaweed-associated fish community (Fig. 5a). The specific diversity was H' = 2.698 with an Evenness E = 0.596 for 1200 individuals of 23 species. *Seriola quinqueradiata* (42.56%) was dominant, and was accompanied by *Tahmnaconus modestus* (21.11%), *Sebastes inermis* (9.48%), *Hyperoglyphe japonica* (5.90%) and *Enedrias nebulosus* (5.74%). In 1989, nearly the same species were found. The results obtained led to a general cumulative RFD showing *Seriola quinqueradiata* (35.71%) in thi dominant position, and a good diversity H' = 2.536 with an Evenness E = 0.597 for 406 individuals of 19 species. *Thamnaconus modestus* (32.51%) and *Sebastes inermis* (6.40%) were the escort (Fig. 5b). In 1990, fishes sampled were mainly *Seriola quinqueradiata*.

In most of the sampled drifting seaweed, especially in the warm waters, eggs of Pacific Saury *Cololabis saira* were found. In 1989, a large quantity was noticed in the samples collected in Sendai Bay. Most of the fishes captured were juveniles and their biological parameters are given in Tables 1 and 2.

Between the distance from shore and the

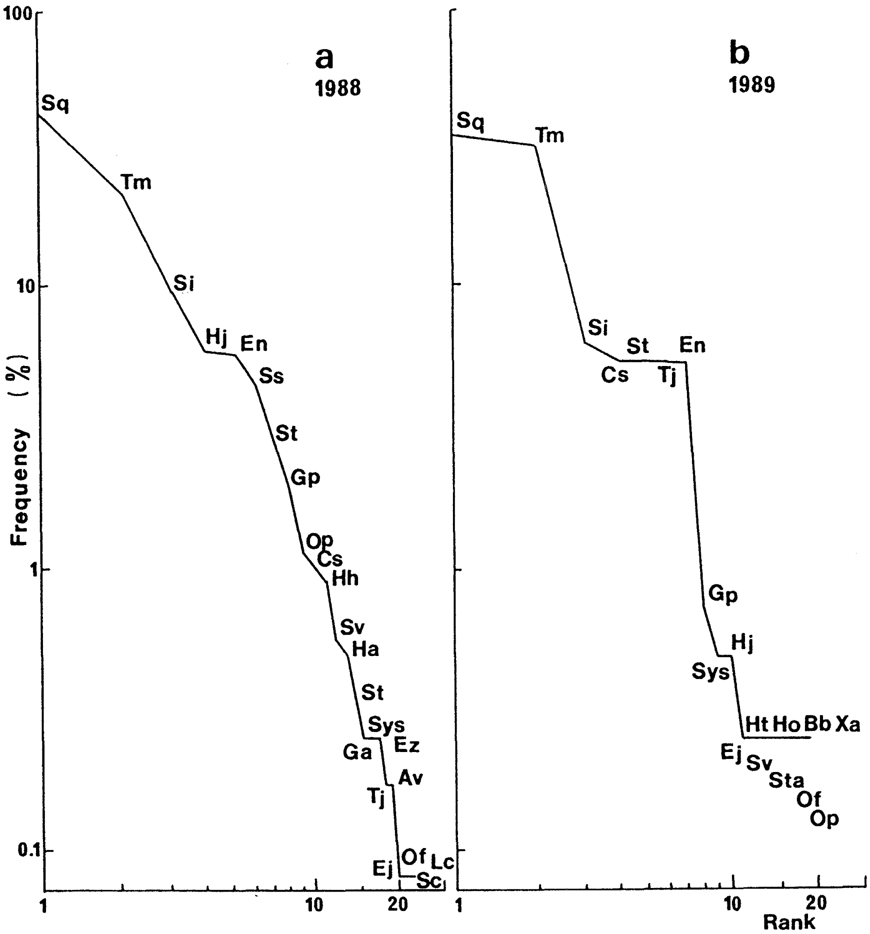

Fig. 5. Cumulative Rank-Frequency Diagrams obtained for the fish communities associated with drifting seaweed in the Tohoku Area in 1988 (a), and in 1989 (b). Species abbreviations as in Tables 1 and 2.

minimum or mean body-length of fish, significant differences were noticed in 1990 with *S. quinqueradiata* (Fig. 6a). The otoliths extracted from these specimens (Fig. 6b) were further proof of the significant differences in the size-growth with the distance from shore, consequently with the drift:

at 70 miles: mean number of rings = 39.25±3.77 with SL = 4.16 ±1.38 cm and Wt = 0.87 ±0.14 g,

at 190 miles: mean number of rings = 46.25 ±4.97 with SL = 3.83 ±0.69 cm and Wt = 1.26 ±0.68 g,

and at 390 miles: mean number of rings = 43.75±5.93 with SL = 2.9±1.15 cm and Wt = 0.63 ±0.35 g.

In 1989, the arithmetic mean for the number of rings counted on *S. quinqueradiata*'s otoliths was equal to 39.71 ±9.41 with SL = 40 ±20.09 mm: while it was 39.5 ±2.29 with SL = 33 ±9.11 mm in *T. modestus*. In 1990, the arithmetic mean for the number of rings in *S. quinqueradiata* was 43.08 ±5.75 with SL = 3.64 ±0.48. No obvious relation could be noticed between the number of rings and the length of the fish (r = 0.445).

Niche relationship

In 1988, most of the 735 stomachs analysed were full:emptiness coefficient was found

Table 1. Biological parameters in fishes associated with drifting seaweed in the Tohoku area in 1988. Symbols are r: correlation factor; a: condition factor or Fulton Index; b: allmetric factor; K: ponderal index ($K = 10^3W/L^3$) in the weight-length relationship ($W = aL^b$). Blank: damaged specimen.

Species	*abbr*.	r	a 10^{-2}	b	K	Length (cm)				Weight (g)			
						Min.	Mean	SD	Max.	Min.	Mean	SD	Max.
Abudefduf vaigiensis	Av												
Cololabis saira	Cs	0.969	0.465	2.779	2.95	2.9	3.32	1.13	4.3	0.07	0.11	1.43	0.24
Enedrias nebulosus	En	0.960	0.338	2.731	2.22	2.9	5.68	1.18	7.4	0.06	0.39	1.61	0.80
Engraulis japonica	Ej												
Erilepsis zonifera	Ez												
Gasterosteus aculeatus	Ga						2.3			0.10			0.12
Girella punctata	Gp	0.845	1.09	3.188	10.55	1.3	1.55	1.08	1.8	0.02	0.04	1.34	0.07
Hexamogrammos agrammus	Ha	0.994	3.375	3.545	11.34	4.2	5.41	1.52	11.4	0.63	1.49	4.47	21.00
Histrio histrio	Hh	0.995	3.53	3.219		1.2	2.62	2.00	11.1	0.09	0.78	9.45	99.45
Hyperoglyphe japonica	Hj	0.995	2.85	2.751	16.33	3.6	7.56	1.55	27.6	0.94	7.44	3.38	262.9
Liza carinata	Lc												
Oplegnathus fasciatus	Of						1.9				0.13		
Oplegnathus punctatus	Op	0.996	1.89	3.154	23.9	1.2	2.64	1.47	4.6	0.04	0.40	3.36	2.40
Sebastes inermis	Si	0.980	1.39	2.939	16.81	2.3	3.53	1.27	6.4	0.20	0.56	2.03	4.50
Sebastes schlegeli	Ss	0.942	0.60	3.538	14.85	0.9	3.16	1.09	4.4	0.01	0.37	1.37	1.36
Sebastes taczanowski	Sta												
Sebastes thompsoni	St	0.952	0.342	5.013	6.32	0.9	1.66	1.33	2.2	0.03	0.04	4.44	0.12
Sebastes vulpes	Sv												
Seriola quinqueradiata	Sq	0.996	0.957	3.039	14.21	1.9	5.97	1.41	15.7	0.10	2.18	2.86	53.53
Stephanolepsis cirrhifer	Sc												
Syngnathus schlegeli	Sys					15.8			20.7	1.01			2.24
Thamnaconus modestus	Tm	0.989	1.29	3.095	15.76	1.7	3.75	1.29	6.8	0.08	0.77	2.21	4.79
Trachurus japonicus	Tj						3.0				0.27		

Table 2. Biolobical parameters in fishes associated with drifting seaweed in the Tohoku area in 1989. Symbols are r: correlation factor; a: condition factor or Fulton Index; b: allometric factor; SCI: stomach contents index. Blank: damaged specimen

Species	*abbr*.	r	a 10^{-2}	b	Length (cm)				Weight (g)				SCI	
					Min.	Mean	SD	Max.	Min.	Mean	SD	Max.	mean	SD
Blepsias bilobus	Bb													
Cololabis saira	Cs	0.517	0.849	1.662	2.0	2.22	1.06	2.5	0.03	0.03	1.20	0.04		
Enedrias nebulosus	En	0.971	0.603	2.465	3.6	5.42	1.21	6.7	0.15	0.39	1.63	0.84	4.92	1.98
Engraulis japonica	Ej					1.60				0.03				
Girrella punctata	Gp	0.902	3.664	1.494	1.5	1.66	1.15	2.0	0.07	0.08	1.25	0.11		
Hexamogrammos agrammus	Ha					7.0				4.33				
Hippocampus takakurae	Ht													
Hyperoglyphe japonica	Hj				5.2	5.35	0.21	5.5	4.35	4.80	0.64	5.25	11.78	3.13
Oplegnathus fasciatus	Of													
Oplegnathus punctatus	Op					1.40			0.07					
Sebastes inermis	Si	0.990	2.897	2.701	1.3	4.03	1.49	6.0	0.08	1.25	2.97	4.03	6.96	1.82
Sebastes taczanowski	Sta													
Sebastes thompsoni	St	0.973	2.328	2.759	1.6	2.19	1.21	3.1	0.08	0.20	1.73	0.50	4.43	1.55
Sebastes vulpes	Sv					2.10				0.16				
Seriola quinqueradiata	Sq	0.992	1.183	3.043	1.0	4.04	1.62	11.4	0.01	0.83	4.36	23.87	6.89	2.70
Syngnatuus schlegeli	Sys					18.3			1.56					
Thamnaconus modestus	Tm	0.988	3.963	2.156	1.0	2.75	1.41	4.2	0.04	0.35	2.12	1.03	5.73	2.52
Trachurus japonica	Tj	0.979	3.228	2.310	1.7	2.48	1.23	3.1	0.12	0.26	1.64	0.49	3.79	1.60
Xanthichthys auromarginatus	Xa													

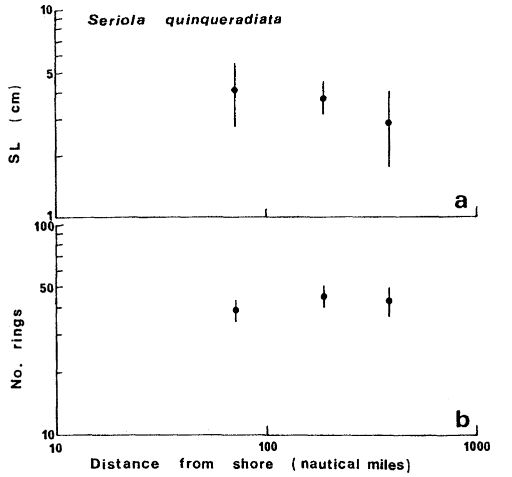

Fig. 6. *Seriola quinqueradiata*: (a) standard length (SL, mean and range), and (b) number of rings counted on otoliths of specimens collected with drifting seaweed in the Tohoku Area at various distances from shore in 1990.

only for *S. quinqueradiata* (6.34), *T. modestus* (10.92), and *H. japonica* (8.82). Except *Enedrias nebulosus*, which fed essentially on gammarid organisms, the dominant food items were copepods in the smallest individuals (< 7 cm) of *S. quinqueradiata*, *T. modestus* and *S. inermis*. No obvious relation was noticed between food organisms of the fish and epiphytal fauna attached to floating seaweed (even if sometimes, some few benthic prey were found in some fish stomachs, their quantity and abundance (< 2%) were not significant compared to the whole diet of the fish). The four species, excluding *E. nebulosus*, were essentially plankton feeders. Some of the fish larvae found in *S. quinqueradiata* were identified as species belonging to the genus *Sebastes*. The food composition of *Hyperoglyphe japonica* was rather complicated and the most diversified, its niche breadth index (H' = 3.385) being the highest. *Pyrosoma* sp. was found in all the stomachs. The other species had relatively simple feeding habit. The smallest niche breadth index was found in *S. inermis* (H' = 1.591), while those of *S. quinqueradiata* (H' =2.211) and *T. modestus* (H' =2.248) were not excessively different. Low similarity values were obtained for all diets when niche overlap indices were high, specially between *S. quinqueradiata*, *T. modestus* and *S. inermis* (values > 0.850; Table 3). In 1989, *Hyperoglyphe japonica* was almost absent from the samples and therefore was not analysed, while *Sebastes thompsoni*, which was among the five dominant species, was studied. All the 271 stomachs were full. Once more again, except *E. nebulosus*, the four species were essentially plankton feeder. The highest niche breadth index was found in *T. modestus* (H' =2.583), and the smallest one in *S.thompsoni* (H' =1.166), while those of *S. quinqueradiata* (H' =1.563) and *E. nebulosus* (H' =1.659) were not excessively different, and the one of *S. inermis* was higher (H' =2.407). Some Gammaridae found in the diet of *E. nebulosus* were identified as *Jassa falcata*, and some Caprellidae as *Caprella penantis*. Some benthic prey were found in the diet of *S. inermis*, the Gammaridae were identified as *Jassa falcata* and represented ca 12% of the whole diet, while some Caprellidae could be identified as *Caprella penantis* and *Caprella danilevskii*, and represented ca 8% of the diet. Similarity values were low (except between *S. quinqueradiata*, *and S. inermis*: 0.707) though niche overlap indices were high, specially between *S. quinqueradiata*, *T. modestus*, and the *Sebastes* sp. (Table 4).

4. Discussion

Drifting seaweed

The shape of the RFD was almost similar and showed a "juvenile community" insinuating that *Sargassum hornerii* was the pioneer leader of the drifting seaweed in the Tohoku Area. Drifting seaweed found in this Area seemed to have a peak of abundance in May-June and decreased in July. This might be induced by a decrease i temperature caused by the mixing of the cold Oyashio and warm Kuroshio currents, by the occurrence of numerous eddies along the Kuroshio Extension, and by the seasonal change in abundance connected to the life history of the seaweed. The bulk of algae found offshore were smaller than those collected near the coast or in Sendai Bay. Most seaweed were caught in healthy conditions with intact holdfasts and receptacles. Nevertheless, the coastal drifting seaweed

Table 3. Diet similarity obtained by Ochiai Index (1957) and niche overlap estimated by Morisita Index (1959) as modified by Horn (1966) in the dominant species of the drifting seaweed-associated fish community in the Tohoku area, in 1988. Species abbrebviations given in Table 1.

	Sq	Tm	Si	Hj	En	
Sq		0.417	0.354	0.544	0.306	Diet
Tm	0.847		0.589	0.476	0.204	Similarity
Si	0.881	0.864		0.481	0.28	
Hj	0.510	0.627	0.487		0.250	
En	0.491	0.462	0.504	0.339		
	Niche overlap					

Table 4. Diet similarity obtained by Ochiai Index (1957) and niche overlap estimated by Morisita Index (1959) as modified by Horn (1966) in the dominant species of the drifting seaweed-associated fish community in the Tohoku area, in 1989. Species abbrebviations given in Table 2.

	Sq	Tm	Si	St	En	
Sq		0.447	0.707	0.354	0.354	Diet
Tm	0.702		0.527	0.316	0.632	Similarity
Si	0.874	0.823		0.272	0.500	
St	0.897	0.676	0.834		0.250	
En	0.290	0.305	0.532	0.271		
	Niche Overlap					

seemed to be younger and freshly detached from their near substratum, since some of their holdfasts were still attached to some coastal stones. While drifting, seaweed might become fragile and weaker due to their ageing combined with rough environmental and oligotrophic conditions. *Sargassum patens*, which was found offshore in the Perturbed Area, was the only typical southern species, while *Coilodesme japonica*, always associated with *Cystoseira hakodatensis*, was the only typical northern species caught exclusively off Hokkaido. The drifting seaweed found in the Tohoku Area seemed to have drifted mainy from the nearest coast:Sendai Bay and its northern part (the southern coast are mainly made of sand beach). Moreover, few species of the Tohoku community were reported in the southern waters of (and off) Japan, and compared with previous findings off Shikoku (OHNO, 1984), the qualitative similarity was very low (0.361). Most of the species described in this study are listed in Matsushima Bay and in the northern part of Sendai Bay-Kinkasan (TAKAMATSU, 1936; SEGAWA *et al.*, 1964). Caprellid fauna associated with floating seaweed, especially *Caprella acanthogaster*, was further proof of drift-origin since this species is characteristic of northern waters and is reported to be from the Tohoku District (HIRAYAMA and KIKUCHI, 1980).

Associated ichthyofauna

All the fishes found with the drifting seaweed in the Tohoku area had been previously reported as species with a tendency to associate with drift algae. Concerning the five dominant species of the present community, they belong to a category called resident, either obligatory as for *Thamnaconus modestus*, *Sebastes inermis* and *Enedrias nebulosus*, or non obligatory like *Seriola quinqueradiata* and *Hyperoglyphe japonica* (SENTA, 1965; IDA, 1986). The faunistic list found in the Tohoku community was not different from previous findings reported from southern waters off Japan. The dominant species and the structure were however different. *E. nebulosus*, which fed essentially on gammarid, the dominant species in Sendai

Bay, was essentially found in nearshore water, while *S. quinqueradiata* and *T. modestus* were collected in offshore water along the Kuroshio Extension. *S. quinqueradiata* (40.83 %) was the dominant species in the Tohoku drifting seaweed-associated fish community, and its escort was composed of *T. modestus* (23.99%), *S. inermis* (8.70%), *E. nebulosus* (5.59%), and *H. japonica* (4.54%); all were plankton feeders and found in close cohabitation, but did not show any strong competition which could lead to the exclusion of one of the dominant species.

Seaweed-fish association: floating nursery

The ecological role of drifting seaweed on the distribution of plankton and the movement of larval fishes, as another important source of5 food especially for *Seriola quinqueradiata* (DAMANT, 1921; ANRAKU and AZETA, 1967), could explain their presence. Shadow of drifting seaweed on the sea surface might have an influence on nychthemeral plankton migration by inducing a kind of rheotropism (phototropism) which could attract the orga nisms during their migration, like rot the fishes (LYON, 1905; KOJIMA, 1957; BOUGIS, 1976; PERES, 1976). Summer set net catches of young *Seriola quinqueradiata* (>15 cm long) were reported by fishermen in Sendai Bay. Juvenile stages were, however, uncommon or never taken. Considering that the spawning ground of this species is located off the southern coast of Japan (south of 34°N) and the role of the Kuroshio warm current on the transportation of the floating objects such as fish eggs and larvae (FUJIMOTO and HIRANO, 1972), juvenile *S. quinqueradiata* presumably used different drifting seaweed, of varying origin according to the spawning season (from March to June), as means of transportation during their migration from south to north along the Kuroshio. When a patch of algae reduced the size, juveniles probably migrated to another fresh, healthy seaweed drifting from the nearest coast, becoming independent and pelagic when reaching to young adult stage. Presence of *Sargassum patens* in offshore samples seemed to support this drift-origin hypothesis form the south. But the most likely hypothesis, taking into consideration the number of rings counted on otoliths, might be a passive drift of eggs and larvae with the warm Kuroshio current from the south to the north. Assuming that the current speed is about 20 miles per day, and that the effective period of survival of fish eggs and larvae floating on the surface of the ocean is about 30 days (FUJIMOTO and HIRANO, 1972), the juveniles of fishes found with the Tohoku drifting seaweed might be probably associated with them since a period of about 10 days, and might have encountered them in the Tohoku Area.

Moreover, *Seriola quinqueradiata*, which was the main catch in May 1990, seemed to be the pioneer species, followed by *Thamnaconus modestus*, and to induce the arrival of the others fishes in this Tohoku community (the "colonization" of this drifting seaweed ecosystem). The mean SL and the mean number of otolith rings of fishes collected remained stable among the drifting seaweeds examined, the significant differences likely showing the origin of different cohorts, thus indicating a type of "turn-over" phenomenon among these fishes. Only juveniles could enter and live around the drifting seaweed, while adults are independent and pelagic ; like if it was a result of a regular flow of individuals passing into the drifting seaweed and replen ishing the stocks with juveniles. Moreover, drifting seaweed seemed to play a key role as spawning ground and eggs propagation for the Pacific saury *Cololabis saira* (KIMURA *et al*., 1958).

These results and observations led to the assumption that drifting seaweed are comparable to a nursery ecosystem, i. e. a feeding and growth place (LENANTON *et al*., 1982; SAFRAN, 1987a and b; 1990a), but a drifting one, where juveniles of fishes could find conditions necessary for existence and survival with shelter and protection, like beneath a Fish Aggregating Device (KOBAYASHI, 1989), but a natural one. Finally, a major implication of this study is that the association of fishes with drifting seaweed might have an influence on recruitment patterns (the seasonal change in oceanographical conditions in the Tohoku

Area-due to the seasonal change of the intrusion of the cold Oyashio into the warm Kuroshio, to the numerous eddies, to the different velocities of the currents, etc.-might have an influence on the life history of the seaweed, therefore on their drifting ability and finally on the rucruitment patterns of the fishes).

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APPENDIX

Drifting seaweed found in the Tohoku area

Species	abbr.	order	class	division
Codium fragile	Cf	Coiales	Chlorophyceae	Chlorophyta
Coilodesme japonica	Cj	Dictyosiphonales	Heterogeneratae	Phaeophyta
Desmarestia viridis	Dv	Sporogonales	〃	〃
Laminaria japonica	Lj	Laminariales	〃	〃
Costaria costata	Cc	〃	〃	〃
Ecklonia cava	Ec	〃	〃	〃
Eisenia bicyclis	Eb	〃	〃	〃
Undaria pinnatifida	Up	〃	〃	〃
Cystoseira hakodatensis	Ch	Fucales	〃	〃
Hizikia fusiforme	Hf	〃	〃	〃
Sargassum patens	Sp	〃	〃	〃
Sargassum hornerii	Sh	〃	〃	〃
Sargassum ringgoldianum	Sr	〃	〃	〃
Sargassum confusum	Sc	〃	〃	〃
Sargassum hemiphyllum	Sh	〃	〃	〃
Sargassum duplicatum	Sd	〃	〃	〃
Sargassum serratifolium	Ss	〃	〃	〃
Sargassum fulvellum	Sv	〃	〃	〃
Asparagopsis hamifera	Ah	Nemalionales	Floridae	Rhodophyta
Grateloupia elliptica	Ge	Cryptomeniales	〃	〃
Rhodoglossum pulcherum	Rp	Gigartinales	〃	〃
Ptilota pectinata	Pp	Ceramiales	〃	〃

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Résumé: Algues dérivantes et ichthyofaune associée ont été échantillonnées dans les eaux du Tohoku, Pacifique nord-ouest, en été 1988, 1989 et 1990, pour analyser la structure de ces communautés et les relations écologiques entre les différentes espèces dominantes de poissons. Les résultats obtunus montrèrent: 1) un pic d'abondance en algues dérivantes dans le Tohoku en mai-juin et une décroissance en juillet. *Sargassum hornerii* représentait l'espèce dominante parmi ces algues jeunes et fraiches qui semblaient venir principalement de la côte proche: baie de Sendai et sa partie nord. Les algues commencàrent à dériver, généralement défaunées, pour gagner l'Extension du Kuroshio où elles se mélangèrent à d'autres espèces-certaines venant du sud. 2) L'espèce dominante de la communauté ichthyologique était *Seriola quinqueradiata*, escortée par *Thamnaconus modestus*, *Sebastes inermis*, *Hyperoglyphe japonica* et *Enedrias nebulosus*. *E. nebulosus*, dont le régime alimentaire était composé essentiellement de gammaridés, fut collecté principalement en baie de Sendai, tandis que les autres espèces, trouvées au large et se nourrissant essentiellement de plancton, semblaient cohabiter sans compétition. 3) Des jubéniles de *S. quinqueradiata* semblaient utiliser les algues dérivantes, le long du courant chaud Kuroshio, comme moyen de transport durant leur migration sud-nord. Néanmons, l'hypothése la plus probalbe, tenant compte du nombre d'anneaux de croissance des otolithes, serait une dérive passive des oeufs et larves avec le Kuroshio durant un maximum de 30 jours (périod effective de survie), puis les juvéniles auraient rencontré les algues du Tohoku et se seraient associés à elles depuis une dizaine de jours. L'ichthyofaune associée était composée de juvéniles, comme si un flot régulier de juvéniles traversait les algues en permanence, comme dans une nourricerie flottante, et pouvant influer sur le déterminisme du recrutement.