Bull. Jpn. Soc. Fish. Oceanogr. 70(2) 105–113, 2006

Ecological significance of leaf litter that accumulates in a river mouth as a feeding spot for young cresthead flounder (*Pleuronectes schrenki*)

Izumi SAKURAI[†1] and Seiji YANAI[2]

This study examined the significance of leaf litter produced by riparian forests to coastal fishes. The survey was conducted at the mouth of the Gokibiru River on the west coast of Hokkaido, Japan. Litter accumulations that were evaluated as coarse particulate organic matter were found at the river mouth throughout the year and the annual litter collection by a sediment trap was estimated to be 25.8 $kg\text{-}C \cdot m^{-2} \cdot yr^{-1}$. An amphipod *Anisogammarus pugettensis* was predominant throughout the year in the litter piles (representing 28.9–35.4% of the total number of invertebrates sampled from the piles) although they did not occur in the sandy bottom areas around the litter piles. Biomass of benthic animals in the litter piles was 1.7 and 2.7 times higher than that in the sandy bottom in June and November, respectively. Young cresthead flounders *Pleuronectes schrenki* less than 180 mm in total length were collected throughout the year in the river mouth and the flounders 70 to 100 mm in length preyed mainly on *A. pugettensis*. Therefore we conclude that litter piles contribute to the growth of young cresthead flounder by providing food.

Key words: amphipod community, *Anisogammarus pugettensis*, biomass, flounder, leaf litter, *Pleuronectes schrenki*, river mouth

Introduction

In temperate deciduous forests, large amounts of litter, such as leaves and branches, are supplied to riverbeds from riparian forests in fall. In particular, leaves account for approximately 70% of the annual litter production (Yanai and Terasawa, 1995a), and form an important component of the diets of freshwater invertebrates (Anderson and Sedell, 1979; Richardson, 1992). Most of the leaf litter is transformed into finer particles or dissolved organic matter in the river through processes of leaching, microbial decomposition, shredding or feeding by macroinvertebrates, and physical abrasion (Petersen and Cummins, 1974; Suberkropp *et al*., 1976; Wallace *et al*., 1982; Cummins *et al*., 1989); these small particles are then carried out to sea. However, large amounts of leaf litter often accumulate on the bottom at the mouths of small streams in areas such as found along the west coast of Hokkaido, Japan, that are characterized by a steep mountainous topography and rapid flow (Hokkaido Forestry Research Institute, 2001). The leaf litter is therefore probably consumed not only in the river; some may be transported to the river mouth without being broken down by biological and physical processes, and utilized as food or as a habitat by marine animals. In tropical and subtropical forests, mangrove detritus contributes very significantly to the nutrition of juvenile prawn inhabiting the upper estuaries of a mangrove swamp (Chong *et al*., 2001). In temperate deciduous forests, however, the significance of riparian vegetation for marine animals has not been fully clarified, although terrestrial organic matter including leaf litter is often utilized as food for birds, fishes and invertebrates on sandy beaches (Brown and McLachlan, 1990).

As part of a forestry policy in Japan, many riparian forests have been maintained to protect fishes or conserve their habitats (Iizuka, 1951; Yanaginuma, 1999). In addition, tree-planting campaigns aimed to propagate coastal fishes have been carried out by several fisheries cooperative associations in Hokkaido and until 1997 a total of 360,000 trees had been planted (Hokkaido Government, 1998). However, it is not yet clarified whether the riparian forests are effective to directly propagate the fishes. In the present study, we attempted to examine what effect leaf litter produced by riparian forests has on coastal fishes. The main goals of the study were threefold: 1) to evaluate the dynamics of leaf litter accumulation in a river mouth, 2) to describe the benthic fauna dependent on leaf litter, and 3) to determine the components of the food chain from leaf litter to coastal fish via benthic animals.

Received September 20, 2005; Accepted January 31, 2006.
[1] Hokkaido Central Fisheries Experimental Station, Yoichi, Hokkaido 046–8555, Japan
[2] Hokkaido Institute of Technology, Sapporo, Hokkaido 006–8585, Japan.
[†] sakuraii@fishexp.pref.hokkaido.jp

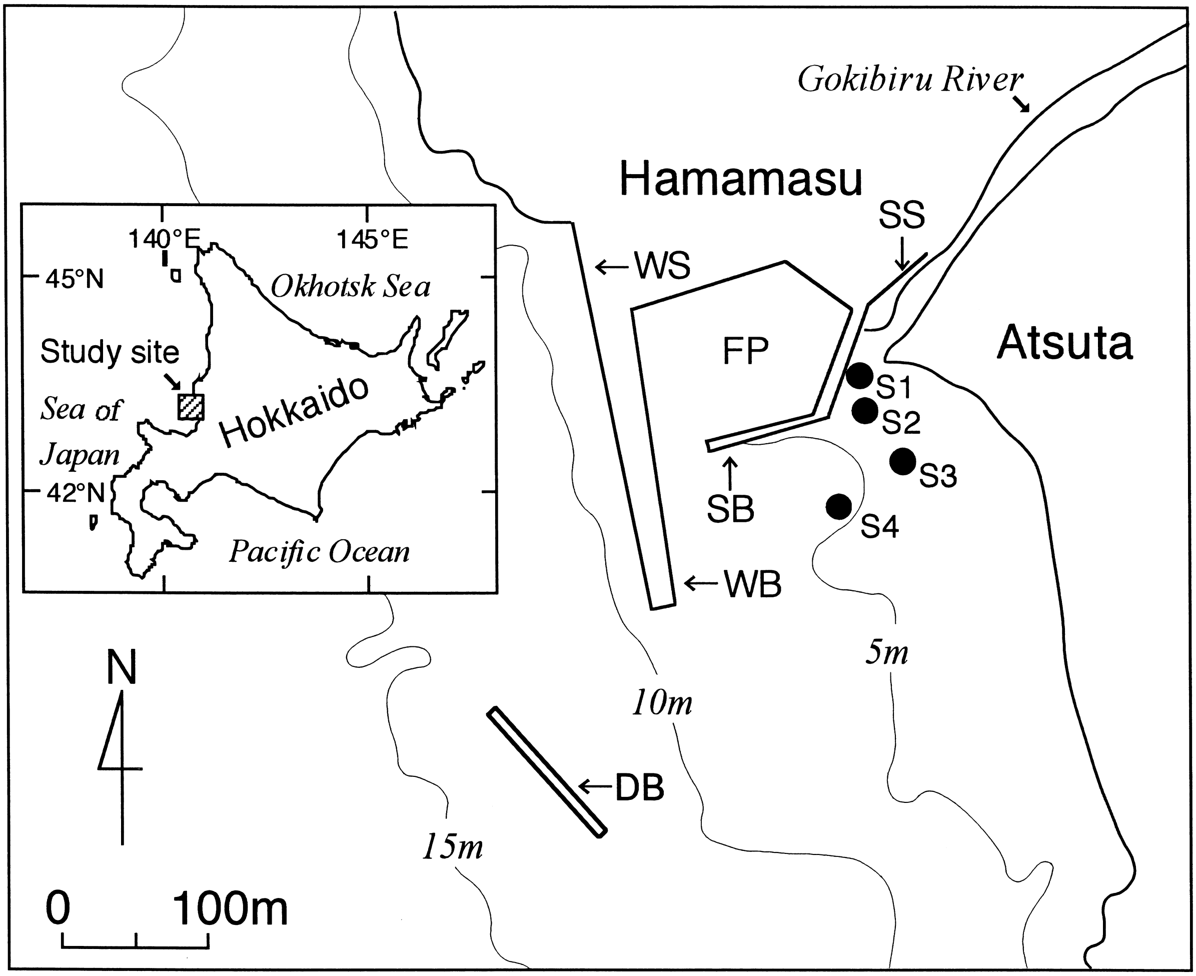

Figure 1. The study area around the Gokibiru River mouth, on the west coast of Hokkaido, Japan. Solid circles indicate the sampling stations. DB: Detached breakwater, FP: Fishing port, SB: South breakwater, SS: South shore protection, WB: West breakwater, WS: West shore protection.

Materials and methods

Study site

This study was conducted at the mouth of the Gokibiru River, on the west coast of Hokkaido, Japan (Fig. 1). This river is approximately 5 km long, has a catchment area of 2,051 ha and flows into the Sea of Japan. The river's riparian vegetation is dominated by cool temperate deciduous forest, including maple (*Acer mono*), alder (*Alnus hirsuta*), oak (*Quercus mongolica* var. *grosseserrata*), elm (*Ulmus davidiana* var. *japonica*), white birch (*Betula platyphylla* var. *japonica*), walnut (*Juglans ailatifolia*), and ash (*Fraxinus mandshurica* var. *japonica*). Dense sasa bamboo comprises the undergrowth (*Sasa* sp.). The riparian forest canopy shades the river surface. At the mouth of the river there is a fishing port on the northern shore, with breakwaters of 430 m total length, including a separate breakwater offshore in water 12 to 13 m depth. A beach extends about 300 m from the river mouth to the south; further south it changes to a rocky shore. The bottom of the river mouth is comparatively steep, with a mean slope of about 1/25 from the shoreline to 15 m deep. Tidal range in the river mouth is only 0.34 m. The bottom is mostly covered with medium to fine sand (median diameter=0.125 to 0.5 mm), although some rocks are visible. Between the river mouth and the West breakwater with about 200 m distance, piles of litter occur on the bottom (Fig. 2). The litter piles are composed of leaves, branches, nuts and seaweed fragments, and the leaves occupy over 90% in the dry-weight composition (Hokkaido Forestry Research Institute, 2001).

Litter samples

To evaluate the annual litter accumulation, litter flowing from the river was collected using a cylindrical sediment trap (base area=20 cm^2, height=50 cm). The sediment trap was fixed in a pedestal set on a wave-dissipating concrete block that was submerged at the river mouth (S1; depth of the upper block surface=0.5 m, depth of bottom=1.8 m,

Figure 2. Photograph of leaf litter that has accumulated at the mouth of the Gokibiru River.

these depth were measured from the water surface at mean sea level). Collections were carried out from June 2000 to December 2001 at 2- to 4-week intervals. Collected sediments were sieved through 1-mm mesh. The residuum on the mesh were rinsed with 1 N HCl solution and distilled water to remove carbonates and then collected as samples of coarse particulate organic matter (CPOM). Because each sample was almost composed of leaves, sorting of CPOM sample was not carried out. The dry weights of CPOM samples were measured to the nearest 0.1 mg with an electronic scale after desiccation to constant weight (within 48 h) at 60°C in a drying oven. The organic carbon content in CPOM was determined using a CHN analyzer (Thermo Finnigan Co., Ltd.; EA1112). In addition, the distance covered by the litter piles was measured along the South breakwater from the point S1 toward offshore (Fig. 1). Measurements were carried out by two divers using a tape measure from August 2001 to July 2002 at about 1-month intervals. Measurement terminal was set to the point in which the area covered by the litter piles became 10% or less by visual observation.

Benthic animal samples

We conducted the survey of benthic animals in the litter piles (S2: depth from the surface at mean sea level=3.2 m). Triplicate sediment samples up to 10 cm in depth were collected by SCUBA diving with a corer (diameter=20 cm) in April, July, September and November 2001 and February 2002. We also carried out the same additional survey in the sandy bottom (S3 and S4: depth from the surface at mean sea level=2.4 and 6.8 m, respectively), aiming at comparing benthic fauna with the litter pile. Because S3 and S4 had too hard substrata for intruding the corer, sediment samples were collected with a Smith-McIntyre grab (sampling area=0.05 m^2, sampling depth=approximately 10 cm) and duplicate collections were carried out in June and November 2001. Each repetition number at sampling by the corer and the grab was decided as both sampling areas become almost equal. All samples were sieved through a 1-mm mesh and then preserved in 5% buffered formalin in the field. After sorting and identification of the benthic animals, the number of each species was counted under a microscope in the laboratory. The dry weight of each species was measured to the nearest 0.1 mg after desiccation to constant weight (within 24 h) at 70°C in the drying oven.

Fish samples

Cresthead flounders (*Pleuronectes schrenki*) is a commercially important fish that is distributed widely off the coasts of northern Japan, eastern Korea, the maritime province of Siberia, Sakhalin, and the Kuril Islands (Nishiuchi, 1991). They were the most dominant fish species in the mouth of the Gokibiru River in a preliminary survey. Therefore, we collected *P. schrenki* with a round haul net (length=10 m, height=5 m, and mesh size=20 mm) in the area including S2, S3 and S4 in June, July, September and November 2001, February and May 2002. The total length of sample was measured to the nearest 0.1 mm with calipers and then the gut contents were extracted and preserved in 5% buffered formalin in the field. Sorting and identification of the gut contents was done using a microscope in the laboratory. The wet weight of each species, or to the lowest identifiable level, of the prey items in the gut contents was determined to the nearest 1 mg. Detritus, leaf and algal material were grouped and weighed together. The wet-weight composition was calculated as the percentage of total weight of each prey item for total stomach content weight. In addition, the body lengths of identified prey were measured to the nearest 0.1 mm under a microscope.

Results

Leaf litter accumulation

The amount of litter that accumulated in the sediment trap was evaluated from CPOM data (Fig. 3). When the amount of litter collection was expressed as values of the organic carbon content, they tended to increase markedly in October and November, and decreased gradually in December through March, with small variations during the other months. Annual litter collection calculated by cumulating data from January to December 2001 was 25.8 $kg\text{-}C \cdot m^{-2} \cdot yr^{-1}$.

The distance covered by the litter piles varied from 2 to 13.5 m throughout the year (Fig. 4); they tended to expand in size in October and November and become reduced in size in December through March as was the amount of litter accumulation.

Benthic fauna

The total species number recorded during the investigation was nine from within the litter piles and twenty-six from the sandy bottom area. The most abundant taxonomic

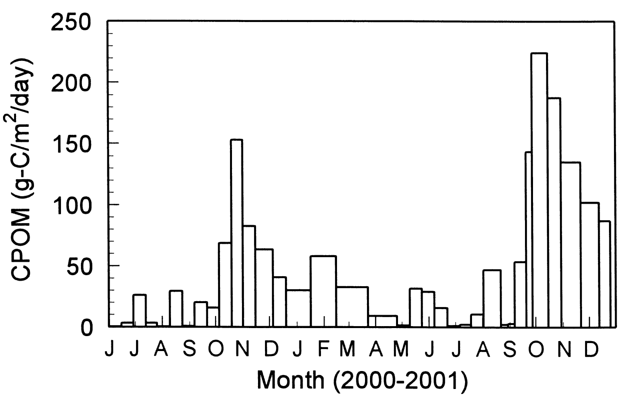

Figure 3. Monthly changes in CPOM that accumulated in a sediment trap from June 2000 to December 2001.

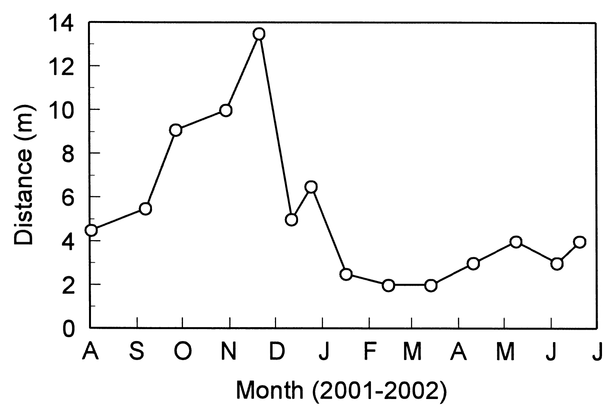

Figure 4. Monthly changes in the distance covered by litter piles from August 2001 to July 2002. The distance was measured along the South breakwater from the point S1 toward offshore.

group was arthropods (19 species), followed by molluscs (7 species), annelids (5 species) and echinoderms (2 species).

The species compositions in the litter piles were similar among the five sampling periods (Table 1). The amphipod *Anisogammarus pugettensis* was the most dominant (representing 28.9–35.4% of the total number of individuals), followed by five amphipods *Melita koreana* (16.9–18.3%), *Melitidae* sp. (14.5–16.5%), *Ampithoe lacertosa* (9.2–10.8%), *Corophium* sp. (6.0–8.8%) and *Liljeborgia* sp. (1.5–5.2%), two isopods *Idotea ochotensis* (8.1–9.6%) and *Excirolana chiltoni* (2.4–9.6%), and the polychaete *Spiophanes bombyx* (1.0–4.6%). The biomass of the benthic animals in the litter pile ranged from 33.2 to 68.7 g-DW$\cdot$m^{-2} and those of *A. pugettensis* and *I. ochotensis* occupied 23.2–33.7 and 20.3–26.4%, respectively.

In contrast, the species compositions in the sandy bottom differed greatly from those in the litter pile (Table 2). The most dominant species in the sandy bottom was the polychaete *Goniada maculata* representing 26.4 and 25.0% of the total number of individuals in June and November, respectively. Other major species in June were three amphipods *Corophium* sp. (13.9%), *Eohaustorius* sp. (8.3%) and *Urothoe grimaldii* (8.3%), and two echinoderms *Scaphechinus griseus* (6.9%) and *Echinocardium cordatum* (5.6%), whereas those in November were *S. bombyx* (22.7%) and the bivalve *Mactra chinensis* (21.6%). The biomass in the sandy bottom was 23.9 and 13.4 g-DW$\cdot$m^{-2} in June and August, respectively, and that of *S. griseus* occupied approximately 50%.

Food items of juvenile flounder

Fifty-seven flounders, *Pleuronectes schrenki*, all of which the total lengths were less than 180 mm, were collected

Table 1. Species compositions (% of total number of individuals) and biomass (g-dry weight$\cdot$m^{-2}) of benthic animals in the litter piles.

Species	Apr. 2001	Jun. 2001	Sep. 2001	Nov. 2001	Feb. 2002
Polychaeta					
Spiophanes bombyx	4.3 (3.1)	2.3 (1.8)	1.0 (0.6)	2.5 (1.6)	4.6 (4.6)
Isopoda					
Idotea ochotensis	8.7 (25.4)	8.1 (23.4)	8.7 (20.3)	9.6 (24.3)	8.2 (26.4)
Excirolana chiltoni	4.8 (14.0)	2.4 (7.5)	3.5 (12.7)	2.8 (10.7)	2.4 (3.5)
Amphipods					
Ampithoe lacertosa	10.1 (11.0)	10.6 (12.5)	9.2 (10.6)	10.5 (10.0)	10.8 (10.0)
Anisogammarus pugettensis	28.9 (23.2)	35.4 (30.5)	32.8 (33.7)	30.6 (32.3)	31.4 (31.2)
Melita koreana	17.5 (9.6)	16.9 (9.9)	17.4 (9.6)	18.3 (8.7)	17.7 (10.1)
Melitidae sp.	14.5 (7.9)	15.2 (8.9)	16.2 (7.1)	16.5 (7.8)	14.8 (5.0)
Corophium sp.	6.0 (2.2)	7.6 (3.0)	8.8 (2.6)	7.4 (2.3)	7.2 (3.6)
Liljeborgia sp.	5.2 (3.6)	1.5 (2.4)	2.4 (2.8)	1.8 (2.3)	2.9 (5.7)
Biomass	68.7	40.8	39.4	36.4	33.2

Value in parenthesis represents the composition (%) of biomass.

through the six fish samplings (Fig. 5). Successive cohorts of the total length were found in June (80 to 110 mm), July (100 to 140 mm) and September (110 to 160 mm) whereas a younger cohort with 70 to 100 mm in total length was found between November and May.

The wet-weight compositions of prey exceeding 2% of the total stomach content weight are shown in Table 3. The specimen with an empty stomach was not observed throughout the survey. Spionid polychaetes were detected from the specimens of each month (representing of 2.6–8.5%), although the occurrence of sabellid polychaetes was restricted to the specimens collected from June to September (17.9–33.2%). *Anisogammarus pugettensis* was found in the specimens except for July and September, with a high

Table 2. Species compositions (% of total number of individuals) and biomass (g-dry weight$\cdot$m^{-2}) of benthic animals in the sandy bottom around the litter piles.

Species	Jun. 2001	Nov. 2001
Bivalve		
Mactra chinensis	1.4 (0.3)	21.6 (6.9)
Polychaetes		
Goniada maculata	26.4 (9.5)	25.0 (16.0)
Spiophanes bombyx	—	22.7 (2.4)
Isopoda		
Excirolana chiltoni	0.8 (0.4)	0.6 (0.5)
Amphipods		
Urothoe grimaldii	8.3 (2.5)	—
Eohaustorius sp.	8.3 (2.0)	4.5 (1.9)
Corophium sp.	13.9 (3.3)	—
Decapods		
Leptochela sp.	0.8 (0.5)	0.4 (0.4)
Crangon affinis	0.6 (0.4)	0.2 (0.2)
Echinoderms		
Echinocardium cordatum	5.6 (20.9)	1.1 (11.7)
Scaphechinus griseus	6.9 (52.7)	2.3 (49.1)
Others	27.0 (7.7)	21.6 (10.8)
Biomass	23.9	13.4

Value in parenthesis represents the composition (%) of biomass.

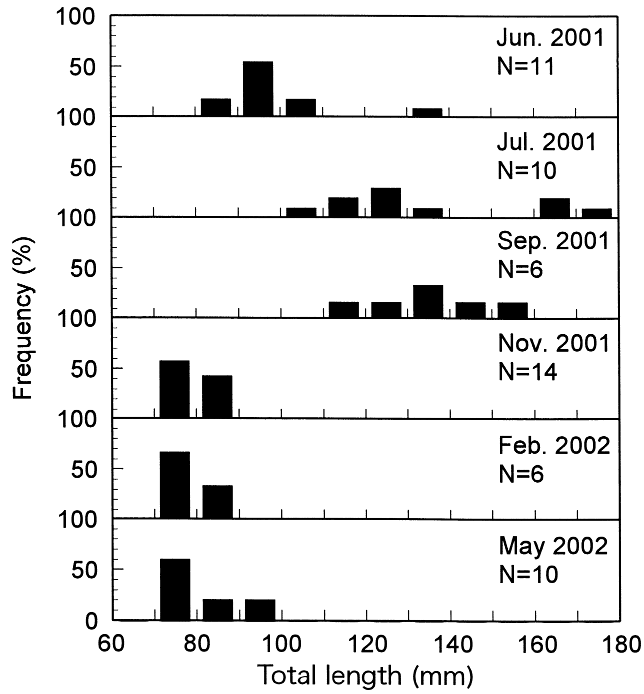

Figure 5. Total length distributions of *Pleuronectes schrenki* collected between June 2001 and May 2002. N represents number of specimen.

Table 3. Wet-weight compositions of prey exceeding 2% of the total content stomach weight of *Pleuronectes schrenki* collected between June 2001 and May 2002.

Prey	Jun. 2001	Jul. 2001	Sep. 2001	Nov. 2001	Feb. 2002	May 2002
Polychaetes						
Spionidae sp.	3.0	4.9	2.6	5.6	2.6	8.5
Sabellidae sp.	17.9	26.5	33.2	—	—	—
Isopoda						
Excirolana chiltoni	—	2.7	3.4	—	—	—
Amphipods						
Anisogammarus pugettensis	65.6	—	—	76.7	90.7	77.5
Corophium sp.	—	8.8	2.2	—	—	—
Decapods						
Leptochela sp.	—	22.4	34.9	—	—	—
Crangon affinis	—	16.4	20.4	—	—	—
Others	13.5	18.3	3.3	17.7	6.7	17.0
Number of specimen	11	10	6	14	6	10

Table 4. Body-length range of prey items in the stomachs of *Pleuronectes schrenki* collected between June 2001 and May 2002.

Species	Range (mm)
Polychaetes	
Spionidae sp.	3.2–5.1
Sabellidae sp.	12.8–20.1
Amphipoda	
Anisogammarus pugettensis	0.3–2.0
Decapods	
Leptochela sp.	11.4–15.7
Crangon affinis	22.3–25.5

percentage (65.6–90.7%). In contrast, *Corophium* sp., *E. chiltoni*, and two decapods *Leptochela* sp. and *Crangon affinis* were restricted to the specimens collected from July and September. The body length of *A. pugettensis* was the smallest among the major prey items in the stomachs (Table 4).

Discussion

Dynamics of leaf litter accumulation

The amount of CPOM in the sediments tended to increase markedly in October and November and then decreased gradually in December through March. Such a change agreed with that in the distance of the litter piles observed along the South breakwater. A similar trend was also found in the riverbed; the amount of CPOM increased markedly in November due to the leaf litter supply (Hokkaido Forestry Research Institute, 2002). The accumulation dynamics of the leaf litter in the river mouth is therefore likely to be linked with that in the riverbed.

In contrast, the amount of the leaf litter supplied from the river is expected to decrease from January to March, because the snow accumulation remarkably reduces the water flowing in this river (Hokkaido Forestry Research Institute, 2002). However, the amount of CPOM increased temporarily in February. In the west coast of Hokkaido including the study area, severe bottom disturbance due to strong wave actions often occurs in winter (Sakurai *et al*., 2001). The high accumulation of CPOM in February is therefore attributable to contaminations of accumulated organic matters due to the disturbance, even through the sediment trap was set at the position of 1.3 m upper on the sea bottom. In addition, in a thaw from April to May, the distance covered by the litter piles expanded due to a higher river discharge (Hokkaido Forestry Research Institute, 2002) whereas the amount of CPOM did not increase. This is probably due to the flush of litter away to offshore without deposition to the sediment trap.

Although the amount of litter collection in the sediment trap does not show exactly that of litter accumulation in the river mouth by the above-mentioned reasons, annual litter collection calculated as a rough standard of annual litter accumulation was 25.8 kg-C $\cdot$ m^{-2} $\cdot$ yr^{-1}. This result is markedly high compared with the amount of suspended organic matter (5–10 g-C $\cdot$ m^{-2} $\cdot$ yr^{-1}) from this river (Hokkaido Forestry Research Institute, 2002). A previous study also found a similar result for suspended organic matter in the Haraki River, which is located in southern Hokkaido and has a catchment area equivalent to that of the Gokibiru River (Yanai and Terasawa, 1995b). In woodland rivers that are surrounded by riparian forest, like the Gokibiru River, therefore, the amount of leaf litter probably exceeds the amount of suspended organic matter which is carried out to the sea.

Benthic fauna dependent on leaf litter

The sandy benthic fauna in the river mouth was characterized by *M. chinensis*, *G. maculata*, *S. bombyx*, *Corophium* sp., *Eohaustorius* sp., *U. grimaldii*, *S. griseus* and *E. cordatum*. This result agrees with that in the Ishikari Bay New Port, which is located about 50 km south from the mouth of the Gokibiru River (Sakurai *et al*., 2000). The benthic fauna in the sandy bottom of both survey sites seems to be continuous. In contrast, the amphipod community in which *A. pugettensis* was dominant throughout the year was found in the litter pile; the species composition of this litter pile amphipod community differed greatly from that of the sandy benthic fauna. The benthic animals indigenous to the litter pile are probably dependent on the leaf litter for habitat or food. In addition, the biomass in the litter pile was 1.7 and 2.7 times higher than that in the sandy bottom in June and November, respectively. Such a high biomass in the litter pile would be also maintained by the abundance of the leaf litter provided as habitat or food.

Anisogammarus pugettensis is distributed across intertidal and subtidal mudflats along the west coast of North America (Waldichuck and Bousfield, 1962), and the east Asian coast from Kamchatka to Sakhalin (Kussakin *et al*., 2001). Gut content analyses of young salmonids revealed that *A. pugettensis* is an important food item for young salmon feeding close to shore (Chang and Parsons, 1975). Waldichuck and Bousfield (1962) observed that *A. pugettensis* was present in large numbers in the vicinity of pulp mills, and seemed to utilize woodchips that had accumulated there as food or habitat. In addition, *A. pugettensis* is considered omnivorous: it has been observed to feed on green algae, diatoms and even frozen fish (Chang and Parsons, 1975). In contrast, because the leaf litter that originated from terrestrial vascular plants is hard to be digested by many littoral animals due to high lignin and cellulose content, it needs to be transformed into digestible substances through processes of microbial decomposition in order to be utilized by the animals as food (Kikuchi and Kurihara, 1988). Although it is known that the leaf litter in riverbeds is consumed by macroinvertebrate shredders such as caddisflies and amphipods after leaching of organic compounds such as tannins and colonization by microbes such as bacteria and fungi (Petersen and Cummins, 1974; Suberkropp *et al*., 1976), a similar consumption of the litter is suggested to occur in the river mouth as well. The shredders actually derive most of their food value from the microbial coating on the litter, not from the plant material itself (Fenchel, 1970; Anderson and Sedell, 1979). *A. pugettensis* is also probably attracted to the litter pile to obtain nutrition from the microbial coating on the litter.

Food chain from leaf litter to flounder via amphipod

Pleuronectes schrenki were collected throughout the year in the mouth of the Gokibiru River. The total lengths ranged 80 to 180 mm from June to September 2001 as successive cohorts, but 70 to 100 mm from November 2001 to May 2002 as the younger cohort. Nishiuchi (1991) noted that the total length of this species reached 80 mm (both male and female) at 1 year of age, 130 mm (male) or 150 mm (female) at 2 years of age, and 170 mm (male) or 190 mm (female) at 3 years of age, and that males and females took two and four years to mature, respectively. In addition, this flounder breeds from March to May in northern Japan (Morita and Ohara, 1965). Therefore the larger specimens were probably more than 1 year in age, and the smaller specimens were less than 1 year in age.

The major prey of *P. schrenki* in the river mouth were several polychaetes and crustaceans. This result is coincident with other young flounders, including *Kareius bicoloratus* (Omori *et al*., 1976), *P. herzensteini* and *P. yokohamae* (Takahashi *et al*., 1987) and *Hippoglossoides pinetorum* (Nishikawa *et al*., 2000). However, the principal species eaten varied with total length except for the spionid polychaetes: flounder 70 to 110 mm in length (sampled in June and November to May) preyed mainly on *A. pugettensis* 0.3 to 2.0 mm in length and flounder 100 to 180 mm in length (sampled in July and September) fed on the sabellid polychaetes, *Leptochela* sp. and *C. affinis* 11.4 to 25.5 mm in length (Table 4). The larger flounder also fed on *Corophium* sp. and *E. chiltoni*. The spionid polychaetes, *Corophium* sp. and *E. chiltoni* were found in both litter piles and the sandy bottom, but *A. pugettensis* was found only in litter piles and *Leptochela* sp. and *C. affinis* were found only in the sandy bottom. Although the sabellid polychaetes were not found in either habitats, many individuals were observed to have settled on a rocky bottom area on the south side of the river mouth. The prey selection of several flounders has been shown to be dependent on prey size (Macdonald and Green, 1986; Martell and McClelland, 1994). Therefore, the foraging area of *P. schrenki* in this river mouth is probably restricted to the litter piles until 1 year of age, and then expands to include sandy and rocky bottom areas as well. The litter piles alone may suffice as foraging areas for young flounder, as the piles contain abundant prey and the camouflage that the leaves provide may allow the flounder to avoid predators.

In the present study, we have described a food chain that extended from amphipod to young flounder and was dependent on leaf litter piled on the bottom at a river mouth. We conclude that litter piles formed at the river mouth contribute to the growth of young flounder by providing food, and therefore evidence to show that the riparian forest would aid conservation of fishery resources has been obtained. Further studies are needed to determine a flow of organic matter in the food chain, as well as population dynamics and secondary production of the amphipods in the litter piles.

Acknowledgements

We thank Professor Hiroshi Morino (Faculty of Science, Ibaraki University) for his valuable advice regarding amphipod identification and Dr. John S. Richardson (Department of Forest Science, University of British Columbia) for his critical reading of the manuscript. We also thank Mrs. Tonomori Kaneta and Takeyasu Nakayama (Hokkaido Central Fisheries Experimental Station) for their assistance in the field, and Dr. Akiko Nagasaka (Hokkaido Forestry Research Institute) for her useful comments on this research.

References

Anderson, N. H. and J. R. Sedell (1979) Detritus processing by macroinvertebrates in stream ecosystems. Ann. Rev. Entomol., **24**, 351–377.

Brown, A. C. and A. McLachlan (1990) Sandy beach ecosystems. In. Ecology of Sandy Shores, eds. A. C. Brown and A. McLachlan, Elsevier, Amsterdam, 197–226.

Chang, B. D. and T. R. Parsons (1975) Metabolic studies on the amphipod *Anisogammarus pugettensis* in relation to its trophic position in the food web of young salmonids. J. Fish. Res. Board Can., **32**, 243–247.

Chong, V. C., C. B. Low and T. Ichikawa (2001) Contribution of mangrove detritus to juvenile prawn nutrition: a dual stable isotope study in a Malaysian mangrove forest. Mar. Biol., **138**, 77–86.

Cummins, K. W., M. A. Wilzbach, D. M. Gates, J. B. Perry and W. B. Taliaferro (1989) Shredders and riparian vegetation. Bioscience, **39**, 24–30.

Fenchel, T. (1970) Studies on the decomposition of organic detritus derived from the turtle grass *Thalassia testidium*. Limnol. Oceanogr., **15**, 14–20.

Hokkaido Forestry Research Institute (2001). Annual Report of Joint Research Project 2000. Hokkaido Forestry Research Institute, Bibai, 5–13 (in Japanese).

Hokkaido Forestry Research Institute (2002). Annual Report of Joint Research Project 2001. Hokkaido Forestry Research Institute, Bibai, 1–14 (in Japanese).

Hokkaido Government. (1998) Trend of Forestry in Hokkaido 1997. Hokkaido Government, Sapporo, 239 pp (in Japanese).

Iizuka, H. (1951) Uotsukirin no Kenkyu. Japan Forest Technology Association, Tokyo, 132 pp (in Japanese).

Kikuchi, E. and Y. Kurihara (1988) Food chain and environmental characteristics. In. Ecology and Eco-technology in Estuary and Coastal area, ed. Y. Kurihara, Tokai University Press, Tokyo, 43–77 (in Japanese).

Kussakin, O. G., Y. I. Sobolevskii and S. A. Blokhin (2001) A Review of Benthos Investigations on the Shelf of the Northeastern Sakhalin. Sakhalin Energy Investment Company, Vladivostok, 91 pp.

Macdonald, J. S. and R. H. Green (1986) Food resource utilization by five species of benthic feeding fish in Passamaquoddy Bay, New Brunswick. Can. J. Fish. Aquat. Sci., **43**, 1534–1546.

Martell, D. J. and G. McClelland (1994) Diets of sympatric flatfishes *Hippoglossoides platessoides*, *Pleuronectes ferrugineus*, *Pleuronectes americanus*, from Sable Island Bank, Canada. J. Fish Biol., **44**, 821–848.

Morita, S. and M. Ohara (1965) Ecological studies of "Kurogashiragarei" (*Limanda schrenki* (SCHMIDT)) of Hokkaido. (I) On the life of spawning population. Bull. Hokkaido Nat. Fish. Res. Inst., **30**, 45–59.

Nishikawa, J., T. Sonoda, I. Sakurai, M. Seto and S. Nakao (2000) Diets of domersal fishes and macrobenthos in the coastal water off Tomakomai, Hokkaido. Nippon Suisan Gakkaishi, **66**, 33–43.

Nishiuchi, S. (1991) Cresthead flounder. In. Fishes and Marine Invertebrates of Hokkaido: Biology and Fisheries, eds. K. Nagasawa and M. Torisawa, Kita-nihon Kaiyo Center, Sapporo, 206–207 (in Japanese).

Omori, M., H. Kinno and I. Nishihata (1976) Study of the habitat of juvenile stone flounder, *Kareius bicoloratus* (Basilewsky), in the estuary of the Nanakita River. Tohoku J. Agr. Res., **27**, 79–91.

Petersen, R. C. and K. W. Cummins (1974) Leaf processing in a woodland stream. Freshwater Biology, **4**, 343–368.

Richardson, J. S. (1992) Coarse particulate detritus dynamics in small, montane streams of southwestern British Columbia. Can. J. Fish. Aquat. Sci., **49**, 337–346.

Sakurai, I., T. Yamashita and S. Nakao (2000) Community structure of the macrobenthos around the Ishikari Bay New Port in Hokkaido, Japan. Fisheries Engineering, **37**, 143–149.

Sakurai, I., H. Hayashi and H. Kuwahara (2001) Sediment environment and macrobenthic community in surf clam bed off Shimamaki coast, Hokkaido, Japan. Nippon Suisan Gakkaishi, **67**, 687–695.

Suberkropp, K. F., G. L. Godshalk and M. J. Klug (1976) Changes in the chemical composition of leaves during processing in a woodland stream. Ecology, **57**, 720–727.

Takahashi, T., T. Maeda, Y. Tsuchiya and T. Nakatani (1987) Distributions and food habits of righteye flounders *Limanda herzensteini* and *L. yokohamae* in Mutsu Bay. Nippon Suisan Gakkaishi, **53**, 177–187.

Waldichuck, M. and E. L. Bousfield (1962) Amphipods in low-oxygen marine waters adjacent to a sulphite pulp mill. J. Fish. Res. Board Can., **19**, 1163–1165.

Wallace, J. B., J. R. Webster and T. F. Cuffney (1982) Stream detritus dynamics: regulation by invertebrate consumers. Oecologia, **53**, 197–200.

Yanaginuma, T. (1999) Mori wa Subete Uotukirin. Hokuto-Shuppan, Tokyo, 246 pp (in Japanese).

Yanai, S. and K. Terasawa (1995a) Varied effects of the forest on aquatic resources in a coastal mountain stream in southern Hokkaido, northern Japan (II). Suspended sediment and organic suspended sediment transported from coastal mountain stream into the Tsugaru Strait. J. Jpn. For. Soc., **77**, 563–572.

Yanai, S. and K. Terasawa (1995b) Varied effects of the forest on aquatic resources in a coastal mountain stream in southern Hokkaido, northern Japan (I). Suspended sediment and organic suspended sediment transported from coastal mountain stream into the Tsugaru Strait. J. Jpn. For. Soc., **77**, 408–415.

河口域に形成される落ち葉堆積場のクロガシラガレイ当歳魚の餌場としての重要性

櫻井 泉[†1]，柳井清治[2]

水辺林が水産資源の涵養に果たす役割を明らかにするため，北海道濃昼川河口域において落ち葉の堆積状況を明らかにするとともに，底生動物相とクロガシラガレイ若齢魚の食性を調査した。その結果，本河口域には落ち葉堆積場が周年観測され，年間堆積量は25.8 kg-C·m^{-2}と試算された。また，落ち葉堆積場では周年を通してトンガリキタヨコエビが28.9～35.4%の編組比率で優占しており，これらは落ち葉堆積場周辺の砂泥底には分布していなかった。さらに，本河口域には周年を通して全長180 mm以下のクロガシラガレイ若齢魚が生息し，このうち全長70～100 mmの当歳魚はトンガリキタヨコエビを主食としていた。これより，本河口域に形成される落ち葉堆積場はクロガシラガレイ当歳魚の餌場として重要であり，餌料供給の観点から水辺林が水産資源の涵養に寄与していることが明らかとなった。

[1] 北海道立中央水産試験場
[2] 北海道工業大学
[†] sakuraii@fishexp.pref.hokkaido.jp