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Impacts of Stream Modification on Habitat Component and Fish Community in Tagawa River

by

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SYNOPSIS

Typical river modification methods were applied to the Tagawa River, the Tochigi Prefecture, Japan, A range of 1.25km was straightened and widened to reduce flooding problem. An investigation of the available habitat and the fish community had been made to grasp the biological influence of the modification. In this research, we carried out the surveys in connection with habitat and fish community before and after the modification in order to conserve the fish habitat, and discussed 1)the relationship between the change of the habitat and the change of fish population, 2)the factors affecting the change of habitat from the hydraulic viewpoint.

The result of this research clearly showed that the method which gave the biggest impact on the habitat was straightening among the various types of modification. As a result, most of slack, mud/sand and riparian vegetation disappeared and run increased and habitat condition became very monotonous. Corresponding to these changes in habitat, most of the species except pale chub were decreased and only pale chub increased.

INTRODUCTION

The River Restoration Project was implemented for the conservation of habitats of the wildlife around the river and the beautiful river scenery since 1990 by Ministry of Construction in Japan. The cases over three thousands of this project had been carried out through Japan until 1993. In order to perform the river management for wildlife around the river, we have to accumulate the information on habitat and manipulate the factors related to habitat such as channel configuration, riparian vegetation and substrate condition, artificial structure and so on. Especially, ecological response by channelization is extremely important to improve the exciting channelization methods and develop a new way of reducing the environmental impacts. There are some studies on the relationship between the aquatic organisms and the habitat changed by river modification(1),(2),(3),(4),(5). The influence of modification on the environment are summarized as follows; 1) channel alterations cause the habitat change such as destruction of riffle, pool and cover, 2) flow and substrate condition tend to be very monotonous and to reduce the habitat diversity, 3)occasionally riparian vegetation disappears, 4) these changes give great impacts on aquatic organisms such as the benthic invertebrate and fish species. However, since these studies do not include the hydraulic viewpoint which is one of factors to control river environment, we do not apply them to river channelization sufficiently.

In this study fish species and habitat were investigated before and after river modification, and the relationship between them are clarified. Furthermore, we analyze the factors which caused the habitat diversity to be monotonous from the hydraulic viewpoints in order to apply this study to the river channelization.

STUDY RIVER AND METHOD

Study river

The Tagawa river which is a tributary of the Kinugawa River flows from a low mountains area in the Nikko City and through a rice field area and the center of the Utsunomiya City. The Tagawa River has a catchment area of 252km^2 and 64km length. 275-day discharge is approximately 2(m^3/s/km^2). This is a rather abundant discharge in

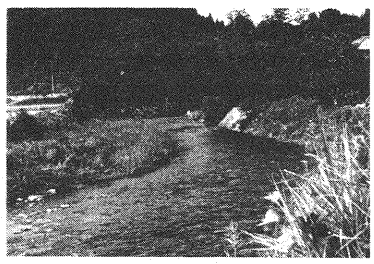


Photo .1 before the modification

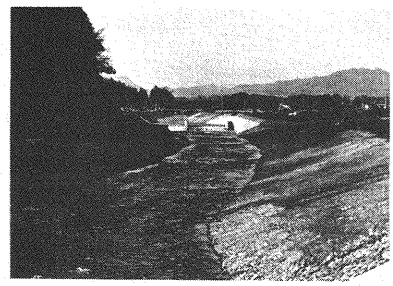


Photo.2 after the modification

Photo.1 and.2 show the situation before and after the modification

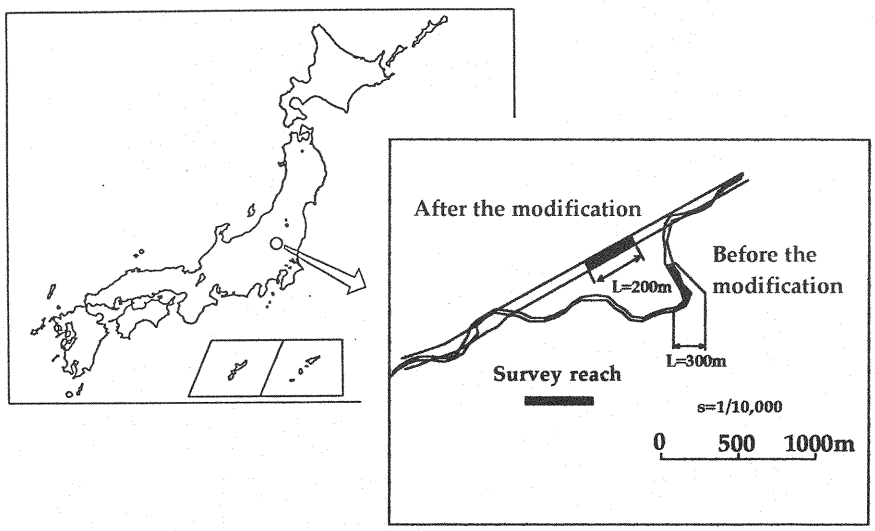


Fig.1 Survey reach before and after the modification

Japan. The water quality is good and the BOD is between 1.5 and 2.0PPm in the middle and the upper segment. The modification of the Tagawa River had been done for a few years. The types of modification on this river are as follows; 1) channel straightening, 2) widening and dredging, and 3) installing revetment, and these types of modification had been usually done in Japan.

Four survey reaches were selected between 28km and 36km from the confluence of the Kinugawa River, on which the investigation have been going on since 1990. This paper describes one of the four observation reaches. Fig.1 shows the survey reach before and after the modification. This reach was shortened from 1250m to 800m, and widened by 1.5 times. A protection lining of concrete was not performed at first but it was installed in March 1991 because the bank erosion had occurred. The object reach has the river bed gradient of 1/250 before the modification and 1/150 after the modification. The investigation length is approximately 300m before the modification and 200m after the modification.

Methods

The investigation concerning about physical environment and the biota was done in the survey reach. In the physical environmental investigation, the distribution of habitat, river bed slope along the axis of channel, diameter of river bed material, water depth and current velocity were measured.

In the investigation of biota, fishes were caught using casting net and scoping net, and the body length and weight were measured. As concerns riparian vegetation, the flora, dominant species, cover degree and socialibility were investigated.

RESULT

The change of fish community

Table.1 shows the change in the fish species and the number of each fish species. Before the modification, the species were 5 species of swimming fish, 6 species of bottom fish, 3 species of stocked fish.

After the modification, the bottom fish, Far Eastern catfish(*Silurus asotus*) and Japanese-eight barbel loach(*Lefua costata echigonia*), were not caught at all. silver crucian carp(*Carassius*) and field gudgeon(*Gnathopogon elongatus elongatus*) which are swimming fish and sand loach(*Gobitis biwae*) and Asian pond loach(*Misgurnus anguillicaudatus*) which are bottom fish did not disappeared but there was an obvious decrease. pale chub(*Zacco platypus*) which is a swimming fish increased a little. The change in the number of stocked fishes have not been observed clearly because the Fishery Cooperative Union stocks the fish every year.

The point is that most species except the stocked fish and pale chub decreased after the modification, this trend is extremely strong for the bottom fishes.

Table.1 Result on fishes caught in the survey reach

		Before the modification		After the modification					
species of fish		Jul-90	Sep-90	Jan-91	Jun-91	Jul-92	Nov-92	Aug-93	Dec-93
swimming fish	Silver crucian carp	8	7			1		5	
	Pale chub		4	1	3		37	7	2
	Japanese fatminnow		1	1		1			
	Field gudgeon	33	19	2	15	6	2	5	2
	Topmouth gudgeon		2			1		1	
bottom fish	Pike gudgeon	3	1		4		1	1	2
	Far Eastern catfish		4						
	Sand loach	22	95			1			
	Japanese eight-barbel loach	12	17						
	Asian pond loach	20	25	4	2			3	1
	Common freshwater goby		2		5	1		6	
stocked fish	Ayu	2			3	4		10	
	Japanese dace	11	8	48	48	89	52	150	12
	Carp		1	1		1			2
total species of fish		8	13	6	7	9	4	9	6
total species of fish		111	186	57	80	105	92	188	21
rate of stocked fish(%)		11.7	4.8	86.0	63.8	89.5	56.5	85.1	66.7

Table.2 Change of habitat before and after the modification

	habitat	Before the modification	After the modification
Substrate condition	mud/sand	26%	0%
	buried gravel	26%	42%
	exposed gravel	48%	0%
	exposed rock	0%	58%
Riparian condition	sand/soil bank slope	5%	35%
	bar	22%	0%
	vegetation on bar	34%) 73%	a few
	vegetation on bank	39%)	0%
	revetment with void	43%	3%
	revetment without void (e.x concrete revetment)	15%	62%
Flow condition	pool	24%	0%
	riffle	20%	0%
	run	37%	99%
	slack	19%	1%

*) The investigation after the modification were implemented in september, 1992.

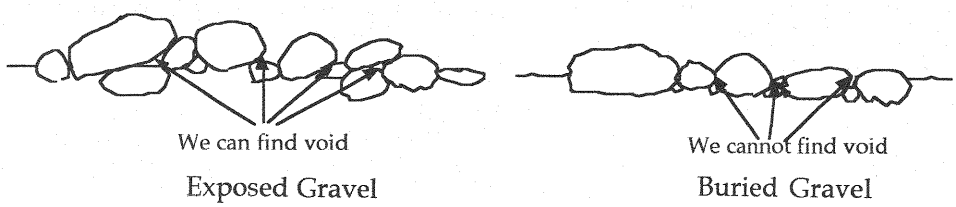


Fig.2 Idea of buried gravel and unburied gravel

The change of the fish habitat

In order to analyze the factors which caused the change in the relationship with the fish habitat, 3 conditions such as substrate riparian and flow condition which are extremely important in fish habitat are classified into detailed parts(6),(7),(8),(9),(10). Table.2 shows the change in habitat before and after the modification based on this classification.

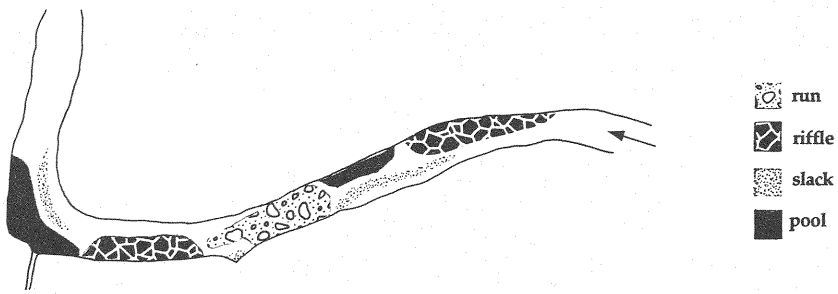
Substrate condition was classified into mud/sand, buried gravel, exposed gravel and exposed rock. In this definition, the buried gravel has silt and sand in the space among gravels and the exposed gravel has open space among gravels as fig.2 shows. Before the modification, 26% of the substrate is mud/sand but it disappears after the modification. Inversely rock is exposed in this reach and 58% of the substrate became exposed rock after the modification.

The riparian condition was classified into sand/soil bank slope, vegetation on bars, vegetation on bank, revetment with void and revetment without void. Before the modification, there was 73% vegetation on bank and bar, and 43% revetment with void. After the modification, however, the vegetation had disappeared and the revetment without void increased instead.

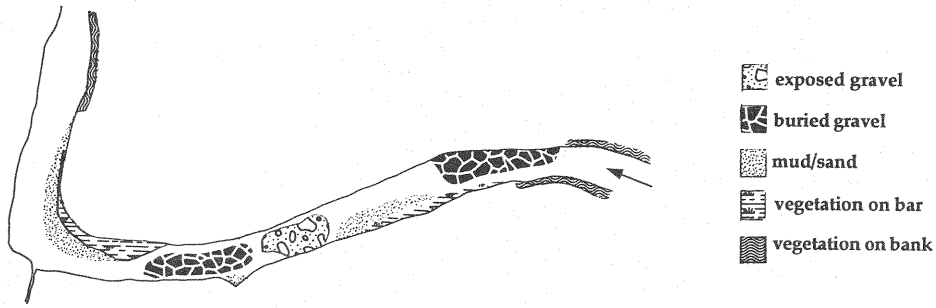
The flow condition is classified into pool, run, riffle and slack. This definition was done from the viewpoint of landscape and physical situation such as current velocity and water depth. The riffle is the part which has white waves and the current velocity is high, and the run is the part which has a waves like wrinkle an current velocity is slow relative to the riffle. The pool has a small current velocity and a large depth. The slack is the part which has a very low current velocity in a hollow bank or at a inner curve. Before the modification, the amount of pools was 24% and there was 19% slack. However after the modification, the pools disappeared, the slack became 1%, and the flow condition became run all over the reach.

Fig.3 shows the substrate, flow and riparian condition before and after the modification. Since the flow condition after the modification was run all over the survey reach, we do not show the results in this paper. After the modification, the substrate condition is monotonous relative to the condition before the modification. Rock is exposed due to the dredging of the river bed, and buried gravel covers on the surface of exposed rock.

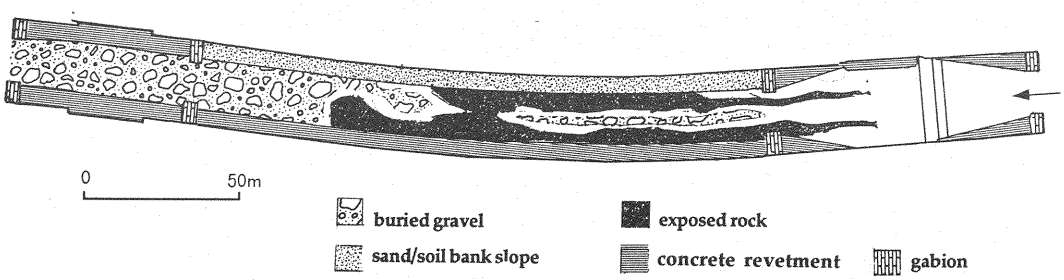
Flow condition has a specific relation with the substrate condition. Run corresponds to the buried gravels, riffle to the exposed gravel and, slack to mud/sand. Since the mud/sand substrate provides the habitat for plant, the disappearance of the slack means not only mud/sand but also vegetation which grows up on mud/sand habitat.



(a)Flow condition before the modification



(b)Substrate and riparian condition before the modification



(c)Substrate and riparian condition after the modification

Fig.3 Flow, substrate and riparian condition before and after the modification

DISCUSSION

The relationship between the change in the fish community and the habitat

Table.3 shows the important habitats for the fishes caught in the Tagawa River in accordance with the classification of this paper based on the representative picture books of the fresh-water fish in Japan(11),(12), and the result of fish survey in the Tagawa River.

As the important habitats for each fish increase or decrease, the number of the fish increase or decrease with the habitat. From this result, the factors of the change can be shaped into four changes in the habitats.

1)The decrease in mud/sand.
Decrease of Bottom fishes except pike gudgeon(*Pseudogobio esocinus esocinus*).

2)The decrease in vegetation.
Decrease of silver crucian carp, field gudgeon, species of loach and Far Eastern catfish.

3)The decrease in slack.
Decrease of Species of loach, Far Eastern catfish, silver crucian carp and field gudgeon.

4)The increase in run
Increase of pale chub.

Table.3 Important habitat for the fishes caught in the Tagawa River

	category of habitat	substrate			riparian			flow				change of fish numbers
	fish name / change of habitat	mud/sand	buried gravel	exposed gravel	vegetation	revetment with void	revetment without void	riffle	run	pool	slack	
		↘	↗	↘	↘	↘	↗	↘	↗	↘	↘	
Swimming fish	Silver crucian carp				◎			○			□	↘
Swimming fish	Pale chub		○					○	◎			↘
Swimming fish	Field gudgeon				◎						◎	↘
Bottom fish	Pike gudgeon	◎									◎	→
Bottom fish	Far Eastern catfish	○			◎	○					○	↘
Bottom fish	Sand loach	◎			◎			○	○		◎	↘
Bottom fish	Japanese eight-barbel loach	◎			◎						◎	↘
Bottom fish	Asian pond loach	◎			◎						◎	↘
Bottom fish	Common freshwater goby		○	○	□			○	○			→

↗ means increase of the habitats or the number of species
↘ means decrease of the habitats or the number of species
→ means there is no obvious change of ther number of species

○ important habitat confirmed by only references
□ important habitat confirmed by only survey
◎ important habitat confirmed by references and survey

Physical environmental changes by the modification

Fig.4 shows the result of the current velocity and water depth before and after the modification. Since the discharge at the investigation after the modification was more than the discharge before the modification, the both range after the modification are located in higher level than the range before the modification. Before the modification current velocity and water depth have a wide range. The feature is as follows;

1)At the pool, the range of current velocity and water depth is distributed broadly.
2)At the slack, the value of current velocity is near zero and water depth is very small.
3)At the riffle, the current velocity is distributed broad range and the range of water depth is small.
4)At the run, the both range is narrow relative to the riffle.

On the other hand, after the modification current velocity and water depth are limited in the narrow range.

As mentioned above, before the modification the condition of habitat is more diverse relative to the condition before the modification. The decrease in diversity made the range of current velocity and water depth small and this indicates that habitat became really monotonous from the physical viewpoint.

The impacts of widening channel on habitat

In order to consider the impacts of the modification on habitat from the hydraulic points, non-dimensional tractive force τ_* were calculated. Before and after the modification the 60% passing diameter of the bed material is $d_{60} = 0.08$(m) and we supposed that roughness coefficient = 0.03.

Before the widening channel τ_* comes to 0.05~0.06 at the discharge = 50(m^3/s), while after widening τ_* does not amount to same value until the discharge = 75~100 (m^3/s) which is almost equal to 1/2 year discharge. As a result it becomes difficult for the bed material to move and once substrate is made flat, it takes long time for riffle and pool to be restored.

Fig.5 shows the occurring zone of the middle scale substrate configuration before and after the widening channel(13). As the discharge increases, the bed configuration cannot come into the alternate-bars clearly. As a result, riffle and pool caused by alternate-bars cannot occur. On the other hand, before the modification width/ Depth(B/H) is small, so that the formation of middle scale substrate configuration is restricted.

The impacts of straightening channel on habitat

Two curves existed in the survey reach before the modification. In these curves the flow in flood concentrates in the outer part of the curve and secondary flow occurs. The fine bed material moves to the inner part so that the outer part ordinarily becomes a scouring zone which corresponds to pool and the inner part becomes a point bar which forms the mud/sand habitat. In addition, the formation of pool could provide the change of bed gradient along axis of channel. Ordinarily, the bed gradient is steep upstream and gentle downstream from pool and these changes result in the formation of various habitats such as riffle and run.

On the other hand, Straightening channel causes the disappearance of flow concentration and secondary flow, and thus the formation of the large scale pool at the outer curve became difficult. As a result the difference among the habitat types were lost.

In the discussion, we mentioned that there could be two factors to increase the diversity of river habitat; one is due to middle scale substrate configuration and another is due to curve. In the Tagawa River, B/H is small before the modification so that the hydraulic condition is not in the occurring zone of middle scale substrate configuration, however a large pool are maintained at the sharp curve. As a result, not only pool but also other various habitat types are able to be found in the survey reach. After the modification B/H increases instead of the disappearance of the curve from the viewpoint of the maintenance of habitat diversity. However, the decrease in the tractive force prevents the alternate-bars from forming. As a result,various types of

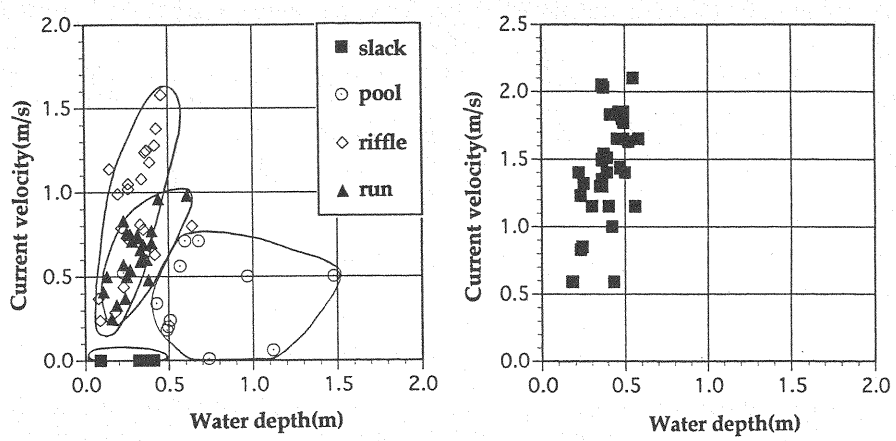


Fig.4 Result of current flow and water depth before and after modification

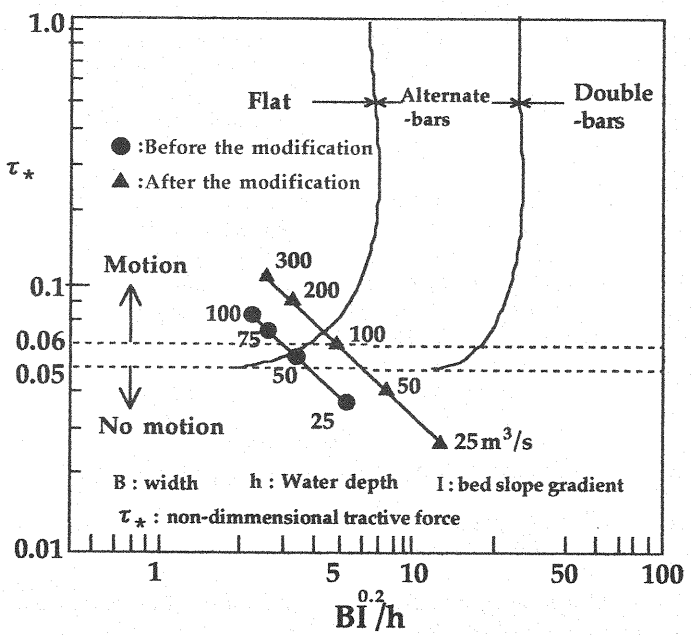


Fig.5 Occurring zone of middle substrate morphology before and after modification

habitat are lost. Supposing that the alternative-bars are formed, the diversity of habitat after the modification would be less than the diversity before the modification, because ordinarily the scale of configuration caused by sharp curve has much larger than those caused by middle scale substrate configuration.

CONCLUSION

The modification which gave the biggest impact on the habitat in the Tagawa River is straightening the stream channel. This type of modification causes the pool, riffle, slack, mud/sand and vegetation to reduce and the habitat diversity decreases. Especially it could be pointed out that the loss of slack gives a great ecological impact because it results in the disappearance of mud/sand which is a important habitat for vegetation. Furthermore, the range of current velocity and water depth becomes small after the modification and the physical diversity also disappeares. As a result of the change in habitat, most fish species population except pale chub decreased obviously and only pale chub increased corresponding to the change of available habitat.

This result includes only 3 years of investigation since the modification, so we need to continue this study of the relationship between recovery of the habitat and the fish community.

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