A challenge to dam improvement for the protection of both salmon and human livelihood in Shiretoko, Japan's third Natural Heritage Site

Futoshi Nakamura[1] and Eishige Komiyama[2]

[1] Laboratory of Forest Ecosystem Management, Graduate School of Agriculture, Hokkaido University, Kita 9 Nishi 9, kita-ku, Sapporo 060-8589, Japan

[2]Wild salmon laboratory, Aza-Yobihito 159-119, Abashiri City 099-2421, Japan

Article type: Report

Corresponding author: Futoshi Nakamura

Laboratory of Forest Ecosystem Management, Graduate School of Agriculture, Hokkaido University, Kita 9 Nishi 9, kita-ku, Sapporo 060-8589, Japan

e-mail: nakaf@for.agr.hokudai.ac.jp

Phone & Fax: +81-11-706-2510

Abstract

The Shiretoko Peninsula was placed on the World Heritage List in July 2005 as Japan's third Natural Heritage Site, being valued for its unique ecosystems formed by the interaction between marine and terrestrial environments. Prior to its listing, however, the International Union for Conservation of Nature and Natural Resources requested the development of measures to allow for the free movement of salmonids through the nominated area via artificial in-stream structures. This report introduces a pioneering effort to modify check dams in order to improve ecosystem linkages. The River Construction Working Group has intensively discussed and implemented restoration projects for three years, and the results have been monitored after implementation. Of 44 streams within the Shiretoko World Natural Heritage site, 14 streams have had one or more in-stream structure(s) built. A total of 123 structures, mainly soil conservation dams, are distributed sporadically in these streams. Following assessment, the Working Group concluded that it would be reasonable to modify 31 structures in 5 streams, including 18 structures that were to be modified before listing. The most suitable design that met local stream conditions was selected, after accounting for salmon passage, adverse impacts on stream environments above and below the construction sites and on fishing grounds, efficiency of construction and ease of post-modification maintenance. Working in cooperation among the group members and parties concerned, we succeeded in restoring salmonids' upstream runs and extending their spawning habitat in streams above some of the dams, while keeping the disaster prevention function of the dams intact.

Keywords

dam modification, ecosystem linkage, marine derived nutrient, salmonid, Shiretoko World Natural Heritage site, restoration

Introduction

The Shiretoko Peninsula is located between the Sea of Okhotsk and Nemuro Strait at the northeastern tip of Hokkaido Island. It retains diverse ecosystems, with primeval environments and rare wildlife species found from the coastline to the peaks of the 1,600-m high backbone mountains. Abundant phytoplankton transported by the seasonal sea ice supports the rich marine ecosystem, and chum salmon and pink salmon run upstream in spawning seasons. Salmon migrating upstream to spawn become a food source for aquatic and terrestrial species (Gende et al. 2002), such as the brown bear and eagle species (Hilderbrand et al. 1999). Salmon die after spawning and are decomposed by aquatic and terrestrial organisms, returning nutrients to forests, lakes and rivers (Ben-David et al. 1998, Nagasaka et al. 2006).

Highly valued for its unique ecosystems formed by the interaction between the marine and terrestrial environments and for its important animal and plant species, the Shiretoko Peninsula was placed on the World Heritage List in July 2005 as Japan’s third Natural Heritage Site.

In August 2004, prior to the inscription of Shiretoko on the World Heritage List, the International Union for Conservation of Nature and Natural Resources (IUCN), which is the advisory body on natural heritage to the World Heritage Committee, requested the development of measures to allow for the free movement of salmonids through the nominated area via artificial in-stream structures. The Government of Japan responded, “The study on needs of fish ladders will be continued taking account of scientific advice, and we are prepared to take measures including installing ladders on as-needed basis.”

To address this issue, the River Construction Working Group (RCWG) under the Shiretoko World Natural Heritage Site Scientific Council (hereinafter referred to as the ‘Scientific Council’) was established at the time of inscription on the World Heritage List in

July 2005. The RCWG was composed of five experts including two fish biologists, a geomorphologist, a river engineer, and a stream ecologist, and representatives of the pertinent governmental organizations (Ministry of the Environment, Forest Agency and the Prefecture of Hokkaido). The RCWG held 12 meetings by January 2008 and conducted an assessment of in-stream structures throughout the Shiretoko Natural Heritage site and its lower reaches.

Many river restoration projects have been carried out throughout the world (Buijse et al. 2002; Bernhardt et al. 2005, Palmer et al. 2005) and in Japan (Nakamura 2006; Nishihiro et al. 2006; Nakano et al. 2008, Nagayama et al. 2008). One restoration measure to restore the river and floodplain ecosystems is to remove dams from rivers (Hart et al. 2002). Case studies of dam removal are concentrated in the United States, and most studies on biotic recovery after dam removal aim to evaluate the effects of elimination of blockage on anadromous fish migration (Stanley and Doyle, 2003).

Although many sediment control and water storage reservoirs have been built in Japan, there have been no efforts to attempt dam removal. Moreover, dam removal is not the only option for restoration of steams and rivers; other restoration alternatives should be discussed carefully depending on the natural and social conditions of the watershed. Unless restoration projects are carefully implemented, adverse effects associated with dam removal and engineering projects, such as the release of fine sediment and/or pollutants that have accumulated behind the dams, may be expected in some cases (Hart et al. 2002). A review of previous dam removals also shows that there has been a limited number of scientific studies examining the pre- and post- removal physical conditions and their effects on stream and riparian biota (Doyle et al. 2000).

The objective of this report is to introduce a pioneering effort to modify check dams in order to improve ecosystem linkages between the forest, stream and ocean. RCWG has intensively discussed and implemented restoration projects for three years, and the results have been monitored after implementation. Although our achievements may not have restored the entire Shiretoko ecosystem, we believe that the steps we have taken represent a milestone that encourages further progress.

Natural and social features of Shiretoko

1) Natural features

The name Shiretoko is derived from the Ainu (indigenous) word ‘sir.etok’, which means ‘the end of mother earth.’ Located at the northeastern tip of Hokkaido Island (Fig. 1), Shiretoko is a narrow peninsula with a length of approximately 70 km and a width of 15 km at its middle (Fig. 2). It is bordered by the Sea of Okhotsk in the west and by Nemuro Strait in the east. The Siretoko mountain range (including the highest peak, Mt. Rausu, at its center, and Mts. Shiretoko, Iou and Onnebetsu) runs along the center of the peninsula. The peninsula is steep, with little flat ground between the peaks and the coastline.

The Shiretoko Peninsula was formed by volcanic activity, and its geology consists of fragile rocks called green tuff and volcanic ejecta. Some areas are still undergoing metamorphic changes by volcanic activity, and frequent land failures and landslides occur in the peninsula. As a result, sediment and rocks are actively supplied into the rivers, making the river environment geologically unstable. Streams in the Shiretoko Peninsula originate in the precipitous mountain range in the center of the peninsula. Most of the streams empty directly into the ocean with the appearance of mountain streams.

The flora is complex, containing both northern- and southern- derived species. Shiretoko is home to many rare animal and plant species and is a globally important habitat for sea birds and staging site for migratory birds. In addition, Shiretoko resides in an area of seasonal sea ice that forms at the lowest latitude of any sea ice in the northern hemisphere. The seasonal sea ice contributes to the extraordinarily high abundance of the phytoplankton community. The prolific phytoplankton provides the food source for abundant zooplankton, which in turn supports the fish and marine mammals of the marine ecosystem.

Eight orders, 12 families, and 42 species of freshwater fish have been found in the streams of Shiretoko (Shiretoko Museum, 2003). Twenty-eight species (about 70% of the total number) are diadromous migratory fish (i.e., fish that spend part of their life cycle in the sea). Characteristically, many of the fish species depend upon the ocean in some way. Among these, six salmonid species naturally reproduce in the streams of Shiretoko, including chum salmon (Oncorhynchus keta), pink salmon (Oncorhynchus gorbuscha), masu salmon (Oncorhynchus masou) and Dolly Varden (Salvelinus malma malma) (Fig. 3). Many of these salmonid species enter streams from the ocean during their spawning season and spawn in gravel deposits on the streambed. Salmonids are a food source for the brown bear (Ursus arctos) and for Blakiston's fish owl (Bubo blakistoni) (Shiretoko Museum, 1999 and 2001) (Fig. 4), which are important species in Shiretoko's wildlife community. Maintaining the salmonid species requires ensuring the connectivity of the ocean and streams and preserving stream habitat available for spawning.

These outstanding natural features of the Shiretoko Peninsula satisfy three of the four criteria set out in the Operational Guidelines 44(a) for the inclusion of natural areas in the World Heritage List: (ii) ecological processes, (iii) natural landscape, and (iv) natural habitat for threatened species.

2) Social features

Salmonids returning from the Pacific Ocean to Shiretoko support the regional fisheries. In Shari and Rausu Towns, salmon and trout commercial fishing is actively practiced. The value in Yen of their salmon and trout catch makes up 20% of the total for Hokkaido prefecture. The region is also the most popular tourist area in Hokkaido, attracting over 2.3 million visitors every year. Shari and Rausu Towns provide accommodations and visitor centers, serving as the gateway for sightseeing in Shiretoko.

On the other hand, because of its fragile geologic conditions, Shiretoko is a region of high risk for mountain-slope disasters. In the past, unexpectedly intense rainfalls have resulted in heavy damages. In one incident, debris flow swept away and buried roads and buildings, and tourists were left stranded at the site. Such natural disasters have repeatedly threatened the livelihood of local citizens in the small towns. For example, in August 1981, heavy rainfall associated with a strong typhoon in the Iwaubetsu Stream triggered a debris flow that destroyed hotels and bridges (Fig. 5). Disaster control structures, including erosion control dams and weirs, have been installed to prevent or to mitigate such damages. These measures have prevented further sediment disasters, enabling the construction of regional economic infrastructure such as roads, bridges and other facilities.

Assessment of check dams and other in-stream structures in Shiretoko

In 2004, the field evaluation report was sent from the IUCN to the Government of Japan. While they favorably evaluated the natural environment of Shiretoko and the Government's management approach, the IUCN raised some concerns and asked for the Government’s feedback. The IUCN's recommendations relating to check dams and other in-stream structures were to 1) accelerate research on the impact of structures on salmon, 2) focus river management on restoration and maintenance of natural river flows and processes, including the removal of structures where there would not be a significant risk to human welfare and livelihood, and 3) install fish ladders to allow for the free movement of salmon through all structures in the rivers of the nominated site. The IUCN sought the Government's commitment to these goals.

The RCWG was organized in response to the IUCN letters and the requests from the World Heritage Committee. The objectives of the RCWG were the following: 1) to evaluate the environment around in-stream structures; 2) to assess structure function in relation to salmon distribution and disaster prevention; and 3) to develop new designs for dam structures according to the results of 1) and 2) above.

The RCWG evaluated in-stream structures with a focus on four salmonid species: chum salmon, pink salmon, masu salmon and Dolly Varden. First, the RCWG developed a method to assess the effects of each structure and its modification on salmon migration. Specifically, we assessed the influence of a structure on upstream movement of salmon; the effect of modification on disaster prevention functions; and the effect of modification work on the surrounding ecosystems. All aspects were comprehensively examined to determine whether or not it would be reasonable to modify the structure. The RCWG then developed an engineering design for each of the structures to be modified. The administrative body could then implement modification sequentially based on the assessment results.

The RCWG defined 'in-stream structure' as any channel-crossing artificial structure that has been constructed in a stream, regardless of the purpose of installation. Of 44 streams within the Shiretoko World Natural Heritage site, 14 streams have had one or more structures built. A total of 123 structures that have been installed and maintained by relevant government agencies is distributed sporadically in these streams. The structures are concentrated in those streams whose lower reaches are bordered by a number of residences, accommodations, roads and bridges.

To carry out a fair and objective assessment, we identified evaluation criteria at each stage of the procedure. These criteria include natural factors preventing upstream run and disturbing habitat conditions (e.g., waterfalls and strongly acidic water), structural problems (elevation gaps between the streambed and the dam height), and the presence or absence of suitable spawning and other habitat types above the structure. If we judged that a structure should be modified from the viewpoint of ecological linkages, then we further examined the potential for debris flow to occur, the risk to human livelihood, life and assets, and any adverse impacts on the surrounding environment that might be associated with modification.

Following this assessment, the RCWG concluded that it would be reasonable to modify 31 structures in 5 streams, including 18 structures for which modification had been planned before listing.

Implementation of modifications and subsequent monitoring in several streams

The modification method for each structure was determined based upon biological and engineering knowledge, with the premise of retaining the intended functions of the structures intact. The most suitable design that met local stream conditions was selected, after accounting for salmon passage, adverse impacts on stream environments above and below the construction sites and on fishing grounds, efficiency of construction and ease of post-modification maintenance (Table 1).

For successful fish passage, a fishway design needs to satisfy the following requirements: a small elevation drop between each ascending step; constant water depth at a certain level; both slow and fast currents, providing holding areas; and a passage route that fish can find easily.

Even if fish passage appears to be successful immediately after modification, its long-term maintenance can be challenging, particularly when the modification design was inadequate. For example, the modified structure may cause bed scouring in its upstream and downstream reaches, producing excessive sediment flow; debris and trash may block the passage route; and the fishway may have a complex configuration. These can constrain the maintenance of the dam and fishway in time and cost. Therefore, to choose a design that ensures sustainable fish passage, it is necessary to evaluate construction efficiency and post-modification maintenance as well as stream morphology and geological setting.

1) Iwaubetsu Stream

The total channel length of Iwaubetsu Stream is 10.5 km, and the watershed area is 41.0 km^2. A town road has been laid along the mainstem. Other human developments along the stream are the town road to Shiretoko-goko Lakes and a bridge in the lower reaches, Iwaubetsu Hot Spring Resort in the middle and a trail to Mt. Rausu in the upper reaches. There is a salmon hatchery in the furthest-downstream watershed. The 1979 and 1981 typhoons triggered debris flow and swept away a part of the town road to the hot spring (Fig. 5).

For the soil conservation dam on the tributary Akai Creek, the RCWG assessment concluded that the influence of dam modification on human properties (residences, roads, bridges, etc.) would be minor, partly because of the limited sediment source in this stream. The dam was physically deteriorated, prompting initiation of modification in fiscal year 2006.

The RCWG decided to cut down the bulkhead of the dam by 1m. The channels above and below the dam were sloped with natural rocks. Rocks were fixed with wires using a stone assembling technique, in an irregular arrangement to create a natural appearance. The bed slope was designed to not impede upstream migration, to restore a view worthy of a world natural heritage site, and to retain the original erosion control function (Fig. 6).

In September 2007 a monitoring survey was carried out for this dam. Downstream of the modified dam, a small dam built by the Town of Shari blocks the salmon run; therefore, we could not monitor the natural migration of salmonids (the Town’s dam was improved later).

Instead, we released pink salmon below the modified dam, and evaluated their upstream migration over the dam. A pair of breeding salmon was allowed to swim above the dam to release pheromones downstream, which attracted the individuals below the dam.

The fish passage study confirmed that eight out of 15 released fish (53%) and 11 out of 15 released fish (73%) migrated above the dam in the first and second trials, respectively. In the first trial, the fish were tagged, which may encumber their behavior and result in a lower percentage of dam passage. Based upon the field observations, the failure of some salmon to pass the dam was not due to structural problems of the modified dam. Instead, some of the released male and female salmon tried to pair up downstream of the modified dam, and other individuals did not attempt to run upstream but swam downstream immediately after release. In spite of these problems in our releasing experiments, we believe that the modification facilitates the upstream run and extends spawning habitat.

2) Rusha Stream

The total channel length of Rusha Stream is 8.0 km, and its watershed area is 21.2 km^2. The stream flows within a National Wildlife Protection Zone of Special Protection Area, where public access is regulated. Shiretoko Forest Road, bridges and a salmon hatchery are present in the lower reaches, and fishing grounds are present in the river's mouth. The 1972 and 1973 rainstorms carried sediment and large pieces of wood downstream, causing a collapse of the hatchery and damage to the fishing grounds and other properties. Following these events, the Town of Shari and the fishery managers requested countermeasures. Three soil conservation dams were then installed in the lower reaches. Although these dams are very low in height, ranging from 1.0 to 2.0 m, the riverbed downstream of the dams has been scoured and the elevation drop has increased. Also, a hatchery weir has been constructed in the furthest-downstream reach.

Pink salmon and chum salmon naturally spawn in Rusha Creek. From August to December, brown bears frequently appear to prey on migrating fish. Although migrating chum salmon had been observed upstream of the soil conservation dams, the flow conditions and elevation drop made passage difficult during the winter (November and December) when water temperature was low. The RCWG concluded that these two dams should be modified to improve salmonid passage. The modifications were implemented in fiscal year 2006.

One of the problems created by these low dams is the occurrence of detached flows out of the concrete structure. The only way for fish to pass the detached flows and the elevation gap is by jumping from the downstream pool. Jumping is an energy-consuming activity, and the success rate is low. In order to improve this situation, the center of the crest was cut down to create a rectangular opening or ‘slit’, and the downstream edge of the crest was carved into a ‘notch’ on both the right and left bank sides. These improvements altered the detached flows previously observed, producing attached flows on the carved surfaces (Fig. 7).

We monitored the upstream run in November, when water temperature is low but chum salmon still migrate upstream for spawning. The redd can be identified from typical gravel-bed feature consisting of mound and pit structure. Salmonid fish returning from the ocean and redds were counted around the two modified soil conservation dams and beyond the most upstream modified dam. When comparing the redd count for chum salmon before and after modification, the percentage of redd counted above the most upstream dam clearly increased after modification. This shows that dam modification facilitated upstream movement and that more adequate spawning habitats are provided in the upstream reaches (Fig. 8). The air temperature in November of 2004, 2006 and 2007 monitored at the nearest observatory in Utoro Town were similar (5.0, 4.7, and 3.0 degrees C, respectively), although precipitation was high in November of 2006 (81, 176, and 66 mm, respectively).

3) Rausu Stream

The total channel length of Rausu Stream is 9.1 km, and its watershed area is 31.2 km^2. The Prefecture Route (Trans-Shiretoko Highway) has been constructed along the Rausu mainstem. There is a salmon hatchery and a hot spring resort in the middle reaches, and downtown Rausu, a national highway, Rausu Fishing Port, and other properties have been built along the lower reaches. The 1961 monsoon rainstorm and 1965 typhoon triggered debris flows, and caused damages in the lower reaches. Therefore, a total of 38 structures have been constructed in the Rausu catchment.

Of these, we modified 18 weir dams by installing slits and fish ladders: five in 2005, six in 2006, five in 2007 and two in 2008 (Fig. 9). The slit in each dam was created at the center of the dam, and a fish ladder was built from the slit to upstream of the dam. Fish may lose their way if the fish ladder extends downstream from the dam, but they can easily find the entrance if the fish ladder extends upstream as in the modification design used in Rausu Stream (Fig. 10). One problem with this style of fish ladder is that a large amount of stream water concentrates in the fishway, and the water velocity in the ladder may exceed the appropriate level for upstream migration of fish. In order to prevent this situation, stream water was split upstream of the dam by the sidewalls of the fish ladder (Fig. 11).

The total numbers of pink and chum salmon and redd were monitored in the area of the18 weir dams from 2005 to 2007. Pink salmon return to their mother rivers earlier than chum salmon. When the numbers of pink salmon and their redd are compared for the same season (middle to late September), the results clearly indicate that the total number of migrating fish and spawning beds was greatly increased by the progressive dam improvements (Fig. 12). The total number of migrating pink and chum salmon was 3300 in 2005, and increased to 5800 in 2006 and more than 6200 in 2007. The total number of redd was 1850 in 2005, and increased to 2700 in 2006 and more than 3700 in 2007.

Concluding remarks

The RCWG held 12 meetings and field surveys from July 2005 to January 2008 and achieved several objectives. The discussion in the Scientific Council and in the general public through media began with dam removal and later diverged into two clearly opposing viewpoints, ‘remove or not’. For a time, we feared that we might not be able to move on to concrete remedial measures. We concluded that dam removal is impossible where dams are necessary to protect human life and property. In the short term, dam modification is the immediate issue. Instead of being frustrated by the argument about dam removal, we should move forward with practical action by modifying dams to improve salmon migration and to restore ecosystem connectivity, even if only in part.

As described in this paper, following repeated discussions among the group members and parties concerned, we succeeded in restoring the upstream run of salmonids and in extending their habitat in streams above some of the dams, while keeping the disaster prevention functions intact. Our progress was favorably evaluated by the IUCN field mission team that visited Shiretoko in February 2008. Our future directions are to evaluate the effectiveness of the remedial actions and to resolve technical issues by monitoring the physical and ecological conditions of the streams. Fortunately, we do not experience a heavy rainfall since the dam modification. We should carefully monitor if dam modification may alter the functions of disaster prevention and ecological linkages, and should make further improvement if necessary.

Modification or removal of other dams may be extremely challenging in light of their disaster prevention function. However, such measures may be possible in the long-term, when ‘soft’ (non-structural) measures, such as relocation of properties from disaster-prone areas, can be applied under agreement with local citizens. In the future, we may be able to use more effective technologies that are suggested by the ongoing monitoring efforts. We hope that the forests, rivers and ocean of Shiretoko, as well as its regional people, may all exist in harmony again.

References

Ben-David M, Hanley TA, Schell DM (1998) Fertilization of terrestrial vegetation by spawning Pacific salmon: the role of flooding and predator activity. Oikos 83: 47-55

Bernhardt ES, Palmer MA, Allan JD, Alexander G, Barnas K, Brooks S, Carr J, Clayton S, Dahm C, Follstad-Shah J, Galat D, Gloss S, Goodwin P, Hart D, Hassett B, Jenkinson R, Katz S, Kondolf GM, Lake PS, Lave R, Meyer JL, O'Donnell TK, Pagano L, Powell B, Sudduth E (2005) Synthesizing U.S. River Restoration Efforts. Science 308: 636-637

Buijse AD, Coops H, Staras M, Jans LH, Van Geest GJ, Grift RE, Ibelings BW, Oosterberg W and Roozen FCJM (2002) Restoration strategies for river floodplains along large lowland rivers in Europe. Freshwater Biology 47: 889–907

Doyle MW, Stanley EH, Luebke MA, Harbor JM (2000) Dam removal: physical, biological, and societal considerations. American Society of Civil Engineers Joint Conference on Water Resources Engineering and Water Resources Planning and Management, Minneapolis, MN, July 30 – August 2

Gende SM, Edwards RT, Willson MF, Wipfli MS (2002) Pacific Salmon in Aquatic and Terrestrial Ecosystems. BioScience 52: 917-928

Hart DD, Johnson TE, Bushaw-Newton KL, Horwitz RJ, Bednarek AT, Charles DF, Kreeger DA, Velinsky DJ (2002) Dam Removal: Challenges and Opportunities for Ecological Research and River Restoration. BioScience 52: 669-681

Hilderbrand GV, Hanley TA, Robbins CT, Schwartz CC (1999) Role of brown bears (Ursus arctos) in the flow of marine nitrogen into a terrestrial ecosystem. Oecologia 121:546–550

Nakamura K, Tockner K, Amano K (2006) River and Wetland Restoration: Lessons from Japan. Bioscience 56: 419-429

Nagasaka A, Nagasaka Y, Ito K, Mano T, Yamanaka M, Katayama A, Sato Y, Grankin AL, Zdorikov AI, Boronov GA (2006) Contributions of salmon-derived nitrogen to riparian vegetation in the northwest Pacific region. J For Res 11: 377-382

Nagayama S, Kawaguchi Y, Nakano D, Nakamura F (2008) Methods for and fish responses to channel remeandering and large wood structure inscription in the Shibetsu River Restoration Project in northern Japan. Landscape and Ecological Engineering 4: 69-74

Nakano D, Nagayama S, Kawaguchi Y, Nakamura F (2008) River restoration for macroinvertebrate communities in lowland rivers: insight from restorations of the Shibetsu River, north Japan. Landscape and Ecological Engineering 4: 63-68

Nishihiro J, Nishihiro MA, Washitani I (2006) Restoration of wetland vegetation using soil seed banks: lessons from a project in Lake Kasumigaura, Japan. Landscape and Ecological Engineering 2: 171-176

Palmer MA, Bernhardt ES, Allan JD, Lake PS, Alexander G, Brooks S, Carr J, Clayton S, Dahm CN, Follstad Shah J, Galat DL, Loss SG, Goodwin P, Hart DD, Hassett B, Jenkinson R, Kondolf GM, Laver R, Meyer JL, O'Donnell TK, Pagano L and Sudduth E (2005) Standards for ecologically successful river restoration. Journal of Applied Ecology 42: 208–217

Shiretoko Museum (1999) Birds in Shiretoko. Shiretoko Library 1. Hokkaido Shimbun Press. 230p. (in Japanese)

Shiretoko Museum (2001) Mammalia in Shiretoko II. Shiretoko Library 3. Hokkaido Shimbun Press. 230p. (in Japanese)

Shiretoko Museum (2003) Fishes in Shiretoko. Shiretoko Library 4. Hokkaido Shimbun Press. 238p. (in Japanese)

Stanley EH, Doyle MW (2003) Trading off: the ecological effects of dam removal. Front Ecol Environ 1: 15–22.

Figure captions

Fig. 1 Location and boundaries of Shiretoko World Natural Heritage Site and locations of in-stream structures.

Fig. 2 A view of the Shiretoko peninsula, exhibiting steep slopes from the mountain peaks to the coastline.

Fig. 3 Salmonid species in Shiretoko: a) chum salmon, b) pink salmon, c) masu salmon, and d) Dolly Varden.

Fig. 4 Brown bears (a & b) and Blakiston's fish owls (c & d) in Shiretoko (provided by Ministry of the Environment, Government of Japan).

Fig. 5 Debris flow damage from the Iwaubetsu Stream in August 1981.

Fig. 6 Dam modification in Iwaubetsu Stream: before and after improvement.

The channel slope was manufactured experimentally from natural rocks to meet three conditions: unimpeded upstream migration, a restored view worthy of a world natural heritage site, and retention of the original erosion control function. The height of the dam was cut down by 1 m, and the channels above and below the dam were sloped with natural rocks. Rocks were fixed with wires. A field test using pink salmon confirmed passage over the modified dam.

Fig. 7 Dam modification in Rusha Stream: before and after improvement.

To remove the obstacle posed by the currents and the vertical drop, a 'slit' was created by cutting down the center of the crest, and a ‘notch’ was created by carving only the downstream edge of the crest on both the right and left bank sides. A field survey after modification found that the number of chum salmon redds increased.

Fig. 8 The redd count for chum salmon before and after modification (the original data were provided by the Hokkaido Prefectural Government).

The percentage of redd counted above the most upstream dam increased after modification. This shows that dam modification improved upstream migration.

Fig. 9 Progress of dam modification in Rausu Stream. The years in the figure indicate progress of the modification from downstream reaches.

Although these low dams are not located within the boundaries of Shiretoko World Natural Heritage site, we advised remedial measures to allow salmon to run upstream and to extend spawning habitat, in order to restore ecological linkages between the headwater basins within the heritage site and the downstream reaches and ocean outside the heritage site. Before Shiretoko was placed on the World Natural Heritage List, a series of low dams had been continuously improved to allow fish passage, but the speed of dam modification was accelerated after the listing.

Fig. 10 Dam modification in Rausu Stream: before and after improvement.

A slit was created at the center of the dam, and a fish ladder was built extending from the slit to upstream of the dam. Fish are able to find an entrance of the ladder easily if fish ladder extends upstream from the dam. Water drains not only into the fish ladder at the center but also through spillways on both sides as indicated by “▽”.

Fig. 11 Upstream conditions of dam modification in Rausu Stream.

In order to avoid all stream water draining into the fish ladder, the stream flow is diverted (① − ③ in the picture) upstream of the dam by the concrete sidewalls of the fish ladder, which are aligned parallel to the stream flow. Arrows in the picture indicate flow direction.

Fig. 12 Changes in the number of upstream run and redd count of pink salmon in Rausu Stream from 2005 to 2007 (the original data were provided by the Hokkaido Prefectural Government). Numbers on the abscissa indicates the locations of 18 weir dams. The locations of weir dams and the dates of modification were shown in Figure 9.

Table 1 Principles for dam modification

1) **Facilitate salmon passage**

   Mitigate elevation drop, water depth and velocity and holding areas to provide for salmonid passage.

2) **Keep construction efficacy**

   While reducing elevation drop, simplify modification design, use local in-stream materials, reduce construction cost and time, etc.

3) **Avoid impacts on the upstream and downstream environments**

   Avoid bed degradation and changes in substrate composition and bed morphology above and below the structure.

4) **Simplify post-construction maintenance**

   Reduce maintenance time and cost

5) **Avoid influences of construction on surrounding ecosystems**

   Avoid adverse impacts of construction on habitat for rare species and other issues.

6) **Avoid impacts of construction on fishing grounds**

   Avoid disturbing fishing grounds.

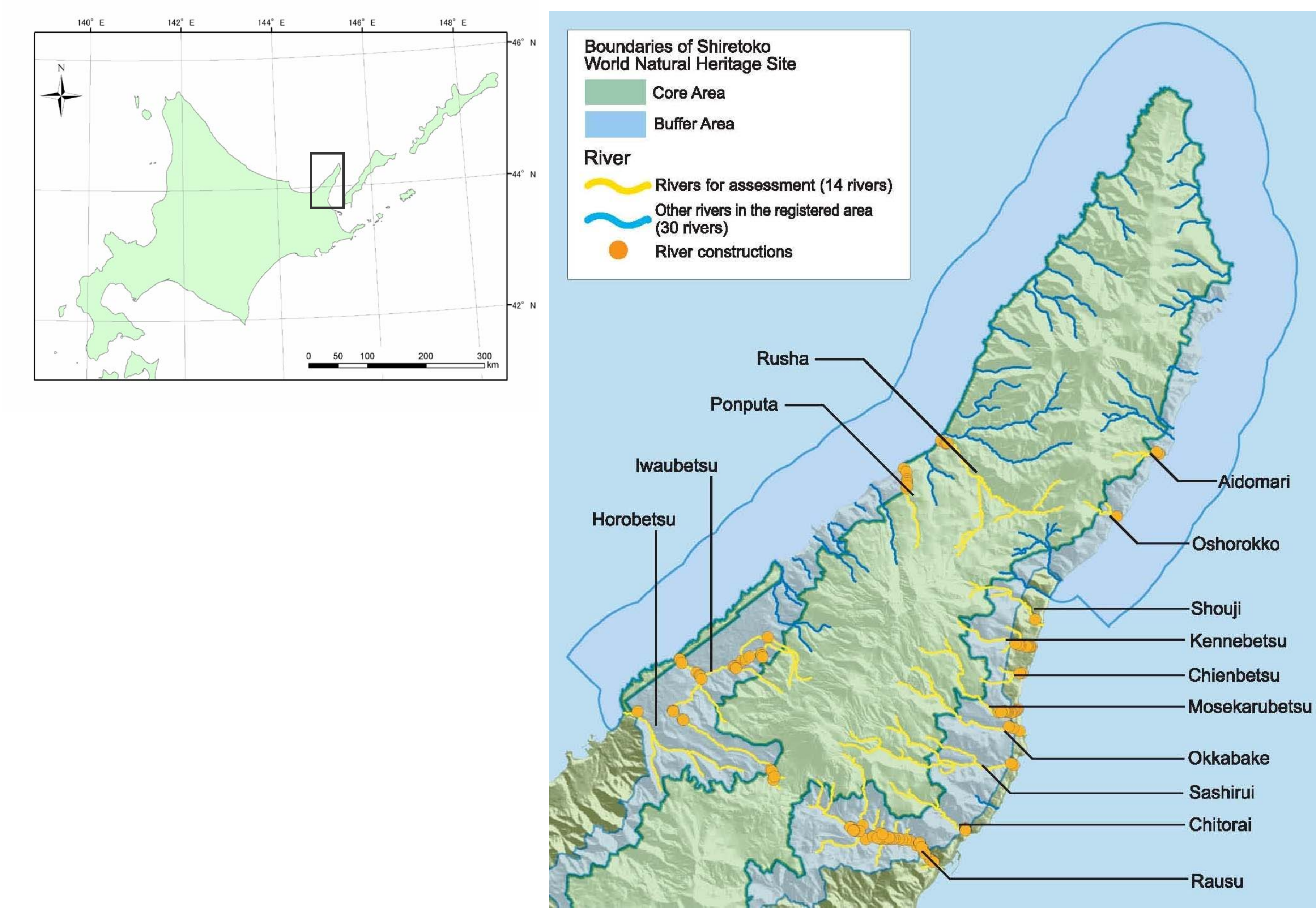
140° E
142° E
144° E
146° E
148° E
46° N
44° N
42° N
N
0 50 100 200 300 km
Boundaries of Shiretoko
World Natural Heritage Site
Core Area
Buffer Area
River
Rivers for assessment (14 rivers)
Other rivers in the registered area
(30 rivers)
River constructions
Rusha
Ponputa
Iwaubetsu
Horobetsu
Aidomari
Oshorokko
Shouji
Kennebetsu
Chienbetsu
Mosekarubetsu
Okkabake
Sashirui
Chitorai
Rausu

Fig. 1

Fig. 2

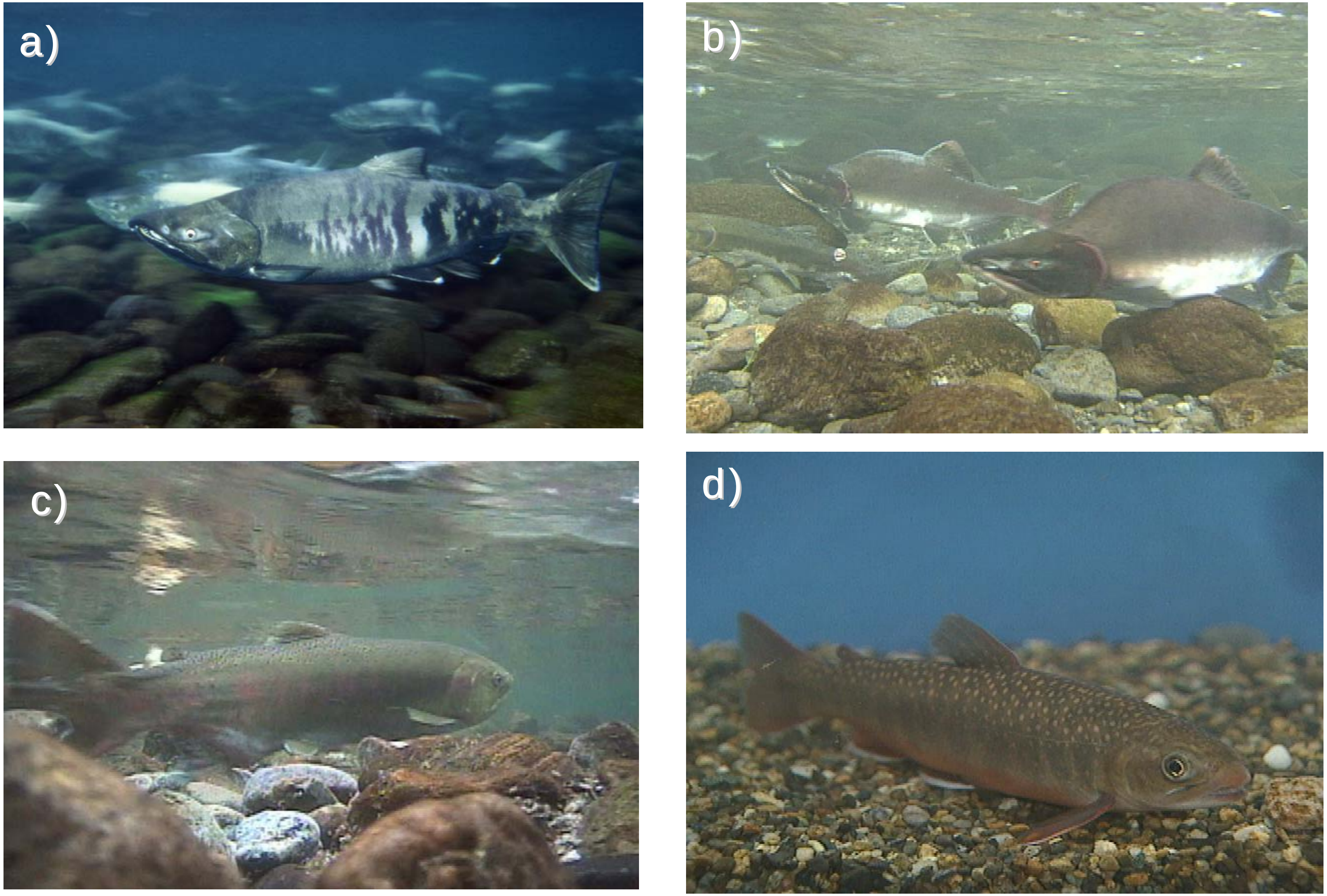

Fig. 3

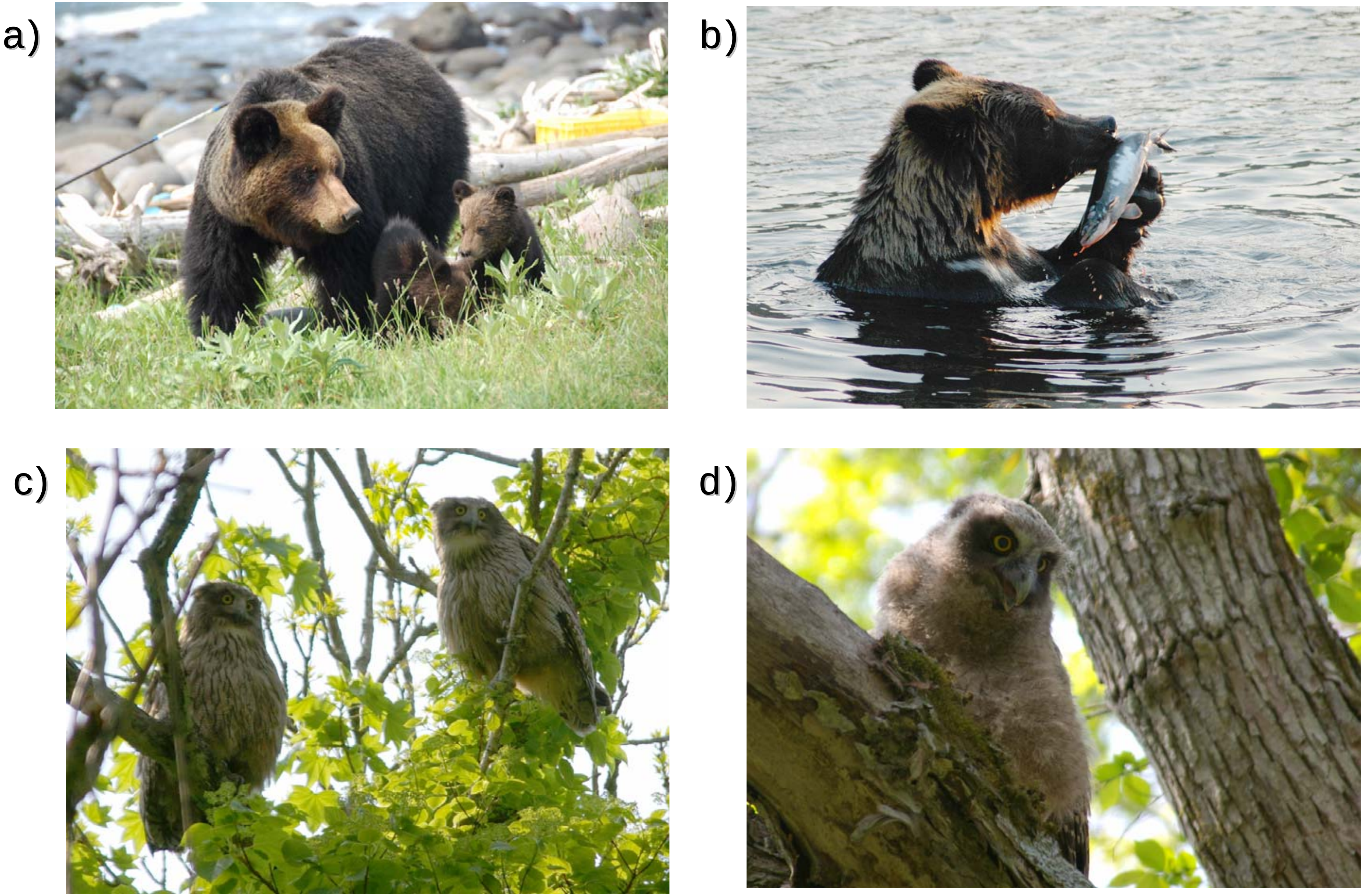

Fig. 4

a)

b)

Fig. 5

Table 1 Principles for dam modification

1) **Facilitate salmon passage**

   Mitigate elevation drop, water depth and velocity and holding areas to provide for salmonid passage.

2) **Keep construction efficacy**

   While reducing elevation drop, simplify modification design, use local in-stream materials, reduce construction cost and time, etc.

3) **Avoid impacts on the upstream and downstream environments**

   Avoid bed degradation and changes in substrate composition and bed morphology above and below the structure.

4) **Simplify post-construction maintenance**

   Reduce maintenance time and cost

5) **Avoid influences of construction on surrounding ecosystems**

   Avoid adverse impacts of construction on habitat for rare species and other issues.

6) **Avoid impacts of construction on fishing grounds**

   Avoid disturbing fishing grounds.

Before

After

Fig. 6

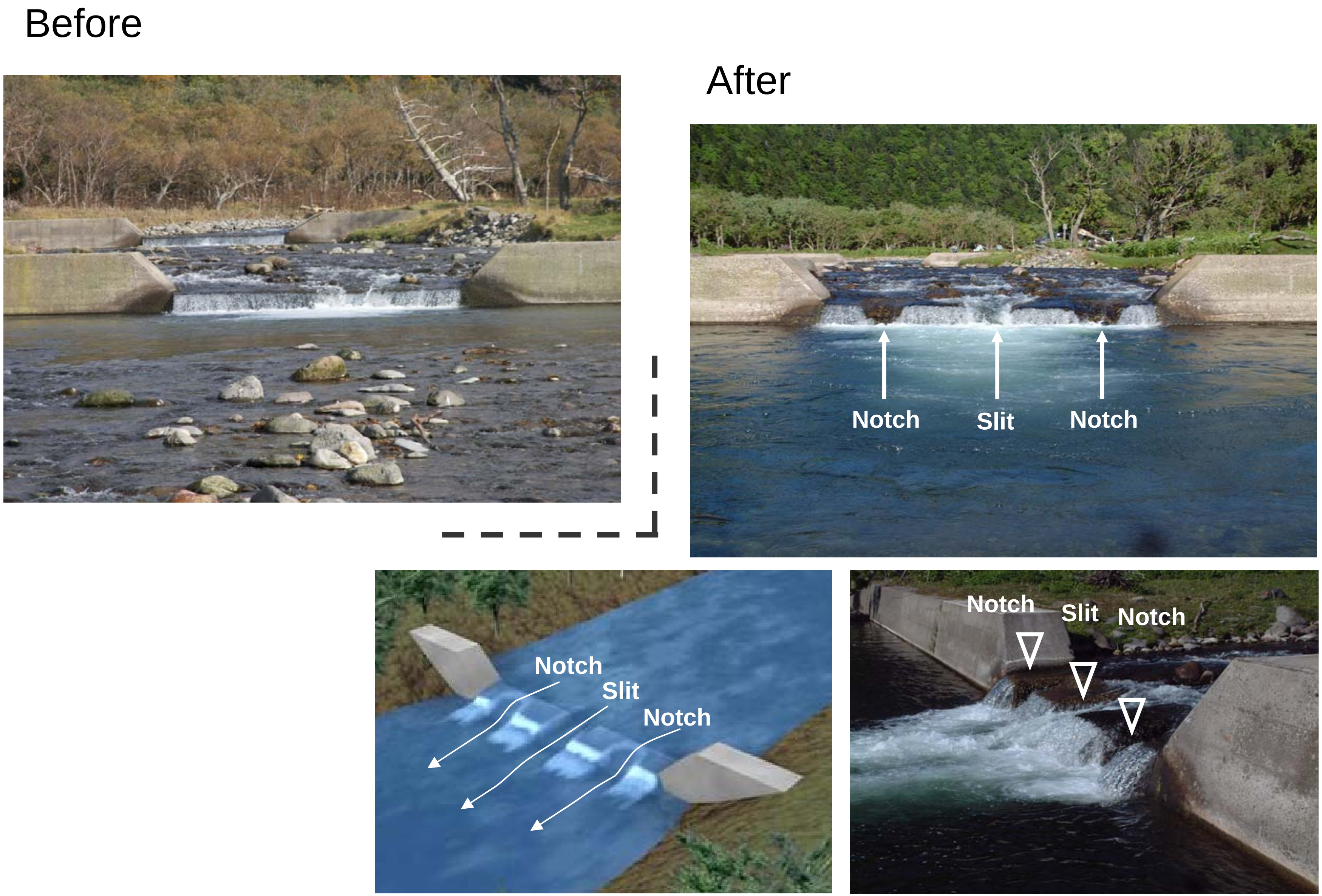
Before
After
Notch
Slit
Notch
Notch
Slit
Notch
Notch
Slit
Notch

Fig. 7

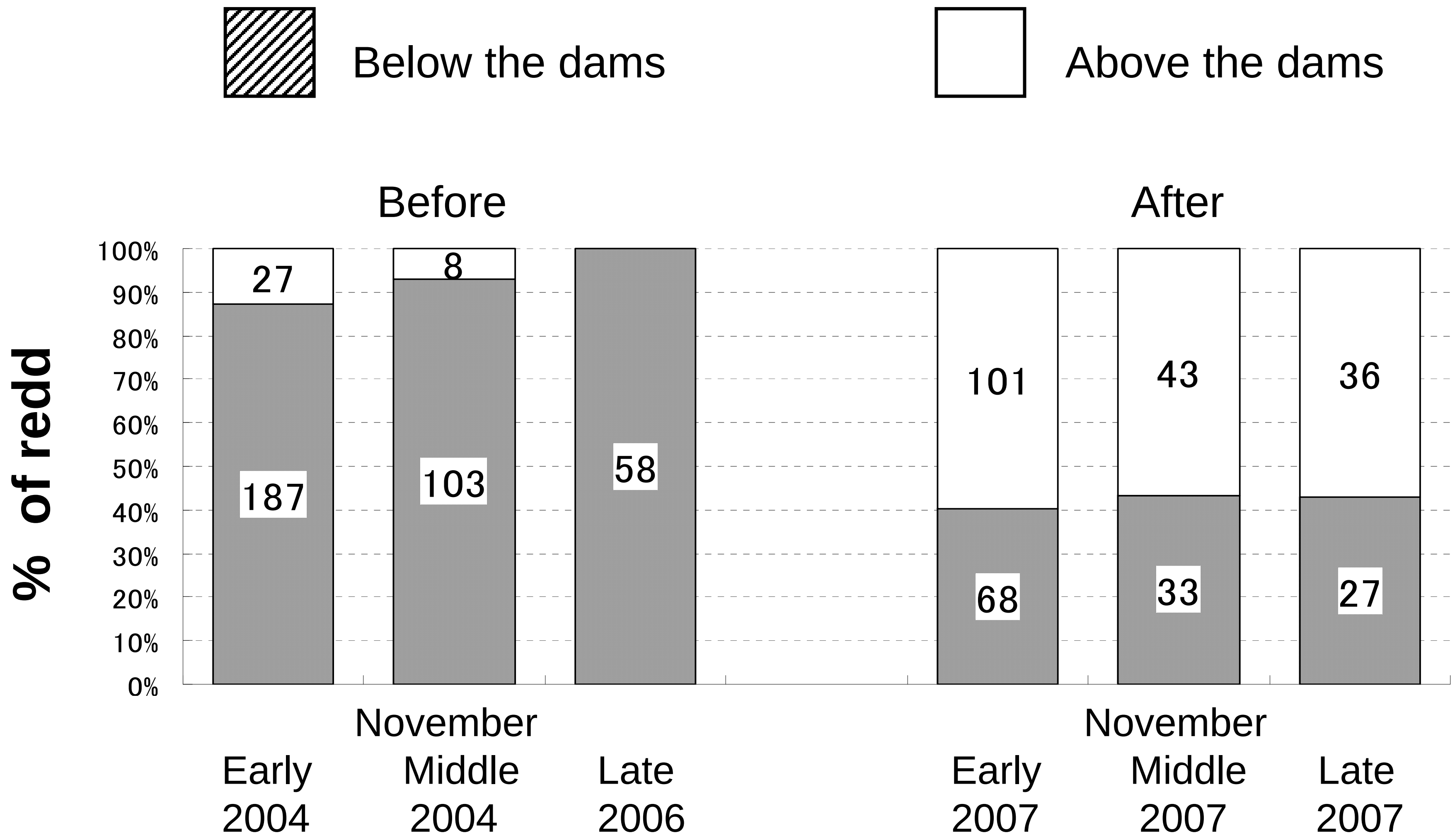
Below the dams
Above the dams
Before
After
% of redd
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
27
187
8
103
58
101
68
43
33
36
27
November
Early 2004
Middle 2004
Late 2006
November
Early 2007
Middle 2007
Late 2007

Fig. 8

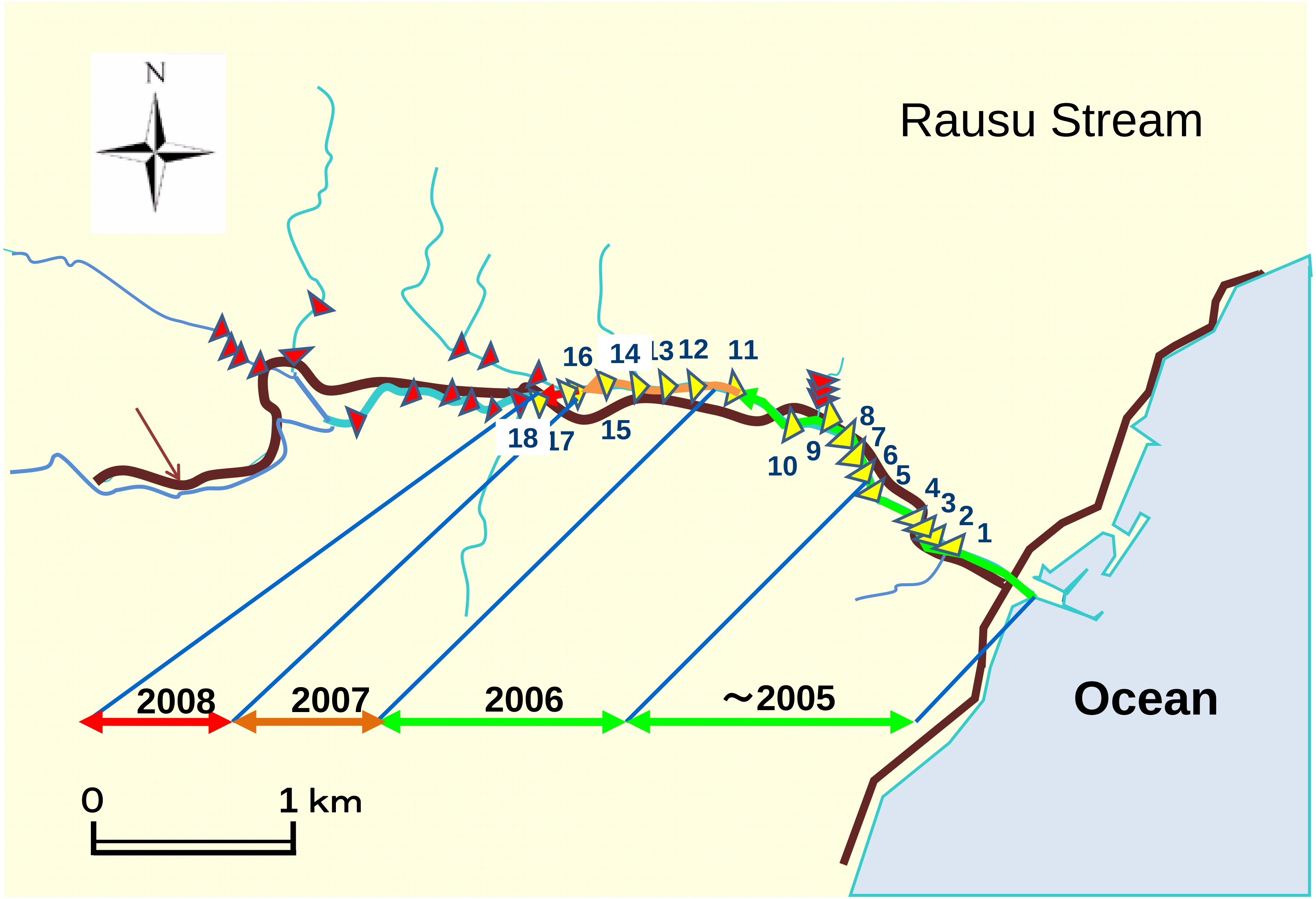
N
Rausu Stream
16
14
13
12
11
18
17
15
10
9
8
7
6
5
4
3
2
1
2008
2007
2006
~2005
Ocean
0
1 km

Fig. 9

Before

After

Fig. 10

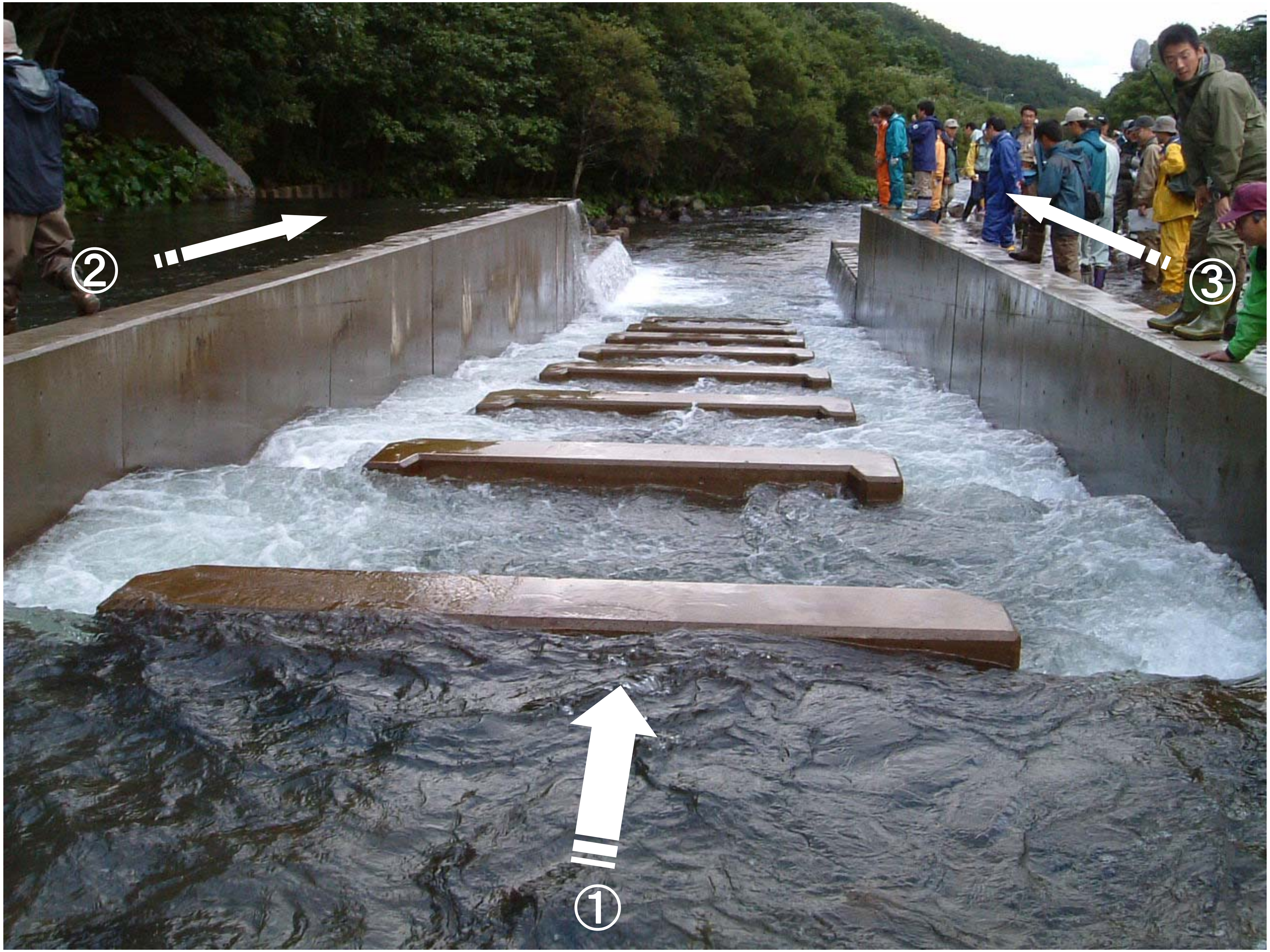

Fig. 11

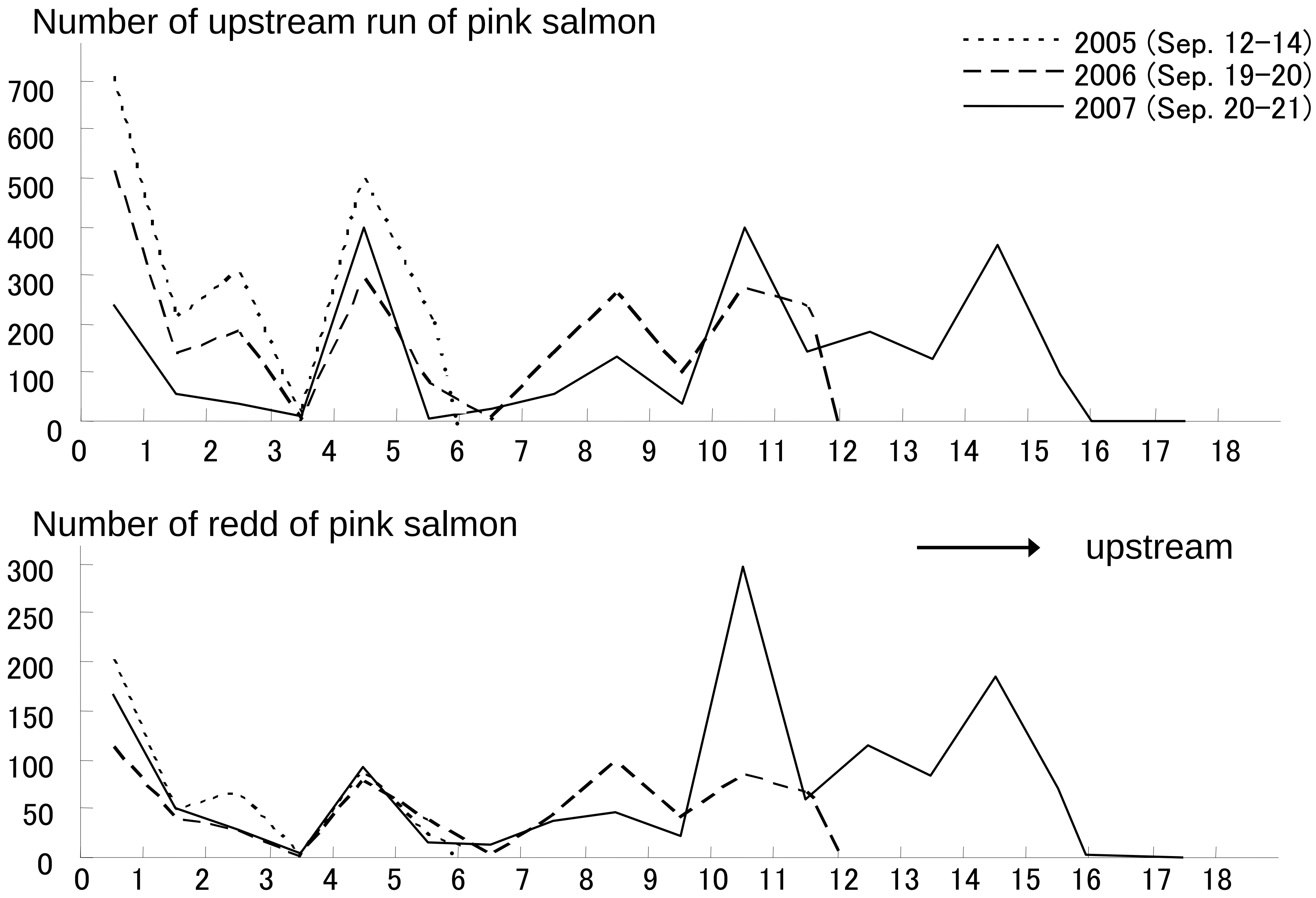
Number of upstream run of pink salmon
2005 (Sep. 12-14)
2006 (Sep. 19-20)
2007 (Sep. 20-21)
700
600
500
400
300
200
100
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Number of redd of pink salmon
upstream
300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Fig. 12