Development of an adaptive marine ecosystem management and co-management plan at the Shiretoko World Natural Heritage Site

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The Marine Management Plan for the Shiretoko World Natural Heritage Site, Japan, provides a case study for adaptive marine ecosystem management and co-management of coastal fisheries. Shiretoko was the third World Natural Heritage Site registered in Japan and earned this title because of its (i) formation of seasonal sea ice at some of the lowest latitudes in the world, (ii) high biodiversity, and (iii) many globally threatened species. The natural resource management plan of the Shiretoko site is characterized by transparency and consensus building, because (i) UNESCO and IUCN require that the plan be sustainable; and (ii) the Government of Japan has guaranteed local fisheries that there will be no additional regulations included in the plan. The Marine Management Plan describes which species and factors are monitored, how these data are evaluated, and how the benchmarks specified by ecosystem management are determined. The Plan will provide a valuable example for the establishment of "environment-friendly fisheries" in Japan and other countries, because it includes voluntary activities by resource users that are suitable for use in a local context, flexible to ecological/social fluctuations, and efficiently implemented through increased legitimacy and compliance. This approach is appropriate for coastal communities where a large number of small-scale fishers catch a variety of species using various types of gear. We develop a method to evaluate fisheries integrity by catch and yield data.

Keywords: adaptive management, co-management, scientific council, Steller sea lions, walleye pollock.

Introduction

Adaptive management predicts and monitors changes in the ecosystem and subsequently reviews and adjusts the management and use of natural resources (Walters 1986). Such predictions and monitoring are best accompanied by feedback controls, such as the verification of hypotheses based on the results of monitoring in order to review and modify management activities.

Marine management in Japan is characterized by a long history of coastal co-management of fishers' organizations (Makino et al., 2008). Co-management is defined as the sharing of responsibilities between governmental institutions and groups of resource users (Persoon et al., 2005). In many countries environmental management is reformulated from exclusive state control to various kinds of joint management in which local communities, indigenous peoples, and nongovernmental organizations share authority and benefits with governmental institutions. Fisheries in Japan face several important challenges, e.g., (i) exclusive use by fisherman with fishery rights/licenses (there are few exceptions for free-fisheries and recreational angling), (ii) lack of full transparency in management procedures, and (iii) lack of objective benchmarks or numerical goals in management plans. Here, we elaborate on the characteristics and issues facing the management of marine ecosystems in Japan. We use the "Multiple-Use Integrated Marine Management Plan for the Shiretoko World Natural Heritage Site, Japan" (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007), as a case study of adaptive marine ecosystem management and co-management of coastal fisheries.

The natural resource management plan of the Shiretoko site is characterized by transparency and consensus building, because (i) UNESCO and IUCN require that the plan be sustainable; and (ii) the Government of Japan has guaranteed local fisheries that there will be no additional regulations included in the plan. These "constraints" seemed to be incompatible with each other. In this paper, we show the solution of these constraints. The solution will characterize Japanese fisheries. In addition, we will present a method to analyze the sustainability from fisheries catch and yield data, which is to be available in the Shiretoko site. Autonomous management by fishers is often based on fisheries data. We use catch and yield data in Shiretoko site (Fig. 1) to evaluate stock and economic status of each resource.

Role and function of the Scientific Council for the Shiretoko World Natural Heritage Site

Marine ecosystems with coastal fisheries

The objective of the Marine Management Plan for the Shiretoko site is to ensure a balance between the conservation of the marine ecosystem and stable fisheries through the sustainable use of fisheries resources in the marine component of the heritage area. According to the IUCN's request, the marine component extends up to 3 km from the coastline, which needed the revision of Natural Park Law in Japan.

The management plan defines measures to conserve the marine ecosystem, strategies to maintain major fisheries resources, monitoring methods for those resources, and policies for marine recreation. The Oyashio shelf region and the seasonally ice-covered areas north of Hokkaido are highly productive and support a wide range of species, including marine mammals, seabirds, and commercially important species in the western subarctic Pacific (Sakurai, 2007). The management plan identifies many indicator species, such as salmonids (e.g., chum, pink, and masu salmon, *Oncorhynchus keta, O. gorbuscha*, and *O. masou masou*, respectively), walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and Steller sea lions (*Eumetopias jubatus*), and also outlines the monitoring and conservation of these important species. They are selected from keystone species, predators at higher trophic levels that probably have a great impact on ecosystems, and endangered species in the waters surrounding Shiretoko.

In addition, the management plan details the vast food web structure of the Shiretoko site (Makino et al. 2009) and includes catch statistics for ten categories of major fisheries resources (Fig. 1). Adaptive management plans usually determine criteria and feedback control measures for indicator species. For example, management plans monitor and enforce conservation actions to satisfy numerical goals within a limited amount of time. Management plans usually devise action plans to achieve these numerical goals or to maintain thresholds for indicator species. However, the present Marine Management Plan for the Shiretoko site (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007) does not include any thresholds or numerical goals for its indicator species, which are currently only monitored. A crucial short-term goal will be to establish such thresholds and/or numerical goals for these indicator species.

The optimal fisheries policy of maximizing sustainable yield from the entire ecosystem does not guarantee the coexistence of all species (Matsuda and Abrams, 2006). Therefore, the goal of the management plan is twofold: sustainable fisheries and biodiversity conservation. Here, we focus on our monitoring efforts of sea lions and walleye pollock as well as the catch statistics for ten categories of fisheries resources (Fig. 1). We consider two periods 1985-89 and 1998-2002, denoted by period I and II, respectively. To evaluate fisheries integrity of the Shiretoko site, we calculate the average yield and catch of resource *i* during period *i* (denoted by C_i^{i} and Y_i^{i}) and calculate the average price $P_i^t = Y_i^t / C_i^t$. We also calculate the coefficient of variation of catch and yield of each resource throughout 1985-2002. We compare C_i^t, Y_i^t and P_i^t between the two periods. If the fish price per unit weight is positively correlated with the fish body size, the fish price is a useful indicator of fisheries integrity. We also calculate the mean trophic level (MTL, Pauly et al. 1998). The mean trophic level of each fish is given by FISHBASE (http://www.fishbase.org/). Trophic level of kelp, common squids, scallop and octopus are set to be 1, 3.6, 2 and 4, respectively.

In addition to fisheries resources, we need to conserve species that are not utilized by fisheries. Sea lions are threatened species and important from conservation viewpoints. Walleye pollock is a target species of fisheries management and is also a prey of sea lions. These species are controllable by several conservation measures. A flow diagram of the adaptive management procedure is presented in Fig. 2.

If some categories of fisheries resources decrease in stock and/or catch, we recommend target switching from the decreased resource to another resource that is temporally abundant (Katsukawa and Matsuda 2003). If all major fisheries resources decrease, the extension or improvement of marine protected areas (MPAs) is effective for fisheries resource management. In

Shiretoko site, fishers autonomously introduced seasonally closed fishing areas to protect spawning fish of walleye pollock in 1995, as well as they decreased the number of fishing boats that fish walleye pollock from 177 in 1997 to 86 in 2004. There are many autonomous closed fishing areas in Japan because the area of closed fishing zone is often flexible from year to year, depending on the stock status (Tomiyama et al. 2005). In this paper, we use the term MPA defined as an area where fisheries are closed or regulated by either government or fishers.

If the stock of walleye pollock decreases, the extension of MPAs, the reduction of fishing capacity, and/or revision of the total allowable catch for this species should be implemented. If the population size of the Steller sea lions decreases, the cull limit, as determined by the potential biological removal (defined below), should be revised, or explosives should be used to scare sea lions away.

We will need to establish clear benchmarks for the catch statistics of major fisheries resources and numerical goals for stock recovery of walleye pollock and Steller sea lions. Such benchmarks should be used to monitor the feasibility of the management plan, and if the plan includes any unfeasible or unrealistic goals, it should be revised (Fig. 2).

Trends in catch and price of fisheries resources

Fig. 1 shows catch amount of the top 10 largest average catch and the mean trophic level (MTL) of Shiretoko fisheries during 1985 to 2002. Table 1 shows some fisheries characteristics of the top 10 taxa of long-term yield and those of long-term catch amount. The coefficient of variation (C.V.) of these resources were relatively stable, ranged from 100% (common squid) to 27% (kelp).

The mean trophic level (MTL) of catch in Shiretoko site was stable throughout 1985-2002. The MTL has slightly increased since 1992 mainly because of increasing catch of salmons. The integrity of marine ecosystem is not characterized by MTL of catch in Shiretoko site.

Among 54 taxa, 26 and 38 taxa changed their catch amount more than 100 and 10 folds, respectively. Among resources in Table 1, catch of walleye pollock and rock fish by 86% and 61% from period I to II, while Price of rock fish increased by 83%. Catch of sardine, anchovy, red king crab (*Paralithodes camtschaticus*), *Sebastes* and herring (*Clupea pallasii*) substantially decreased by 100%, 99.4%, 99%, 97% and 96%, respectively. Sardine (Watanabe et al. 1995), anchovy and herring decreased probably because of natural fluctuation in Japanese waters, while we do not know the reason why red crab king and *Sebastes* decreased. Greenling (*Hexagrammos otakii*) decreased their catch by 70% and the fish price by 64% from period I to II.

There are two major resources in Shiretoko site, chum salmon and walleye pollock. Those were two of largest-yield resource throughout 1985-2002, except in 1996, 97 and 2001 while the 2nd largest yield resource was common squid in 1996, 97 and kelp in 2001 . The largest yield resource was walleye pollock during 1985-92 and chum salmon during 1993-2002. Common squid, kelp, rock fish, *Sebastes* and Pacific cod have at least once been the 3rd largest yield throughout 1985-2002. Sum of the top three largest yield resource ranged from 81% in 1985 to 53% in 1996 of the total annual yield. Since walleye pollock decreased in 1991, Shiretoko fisheries now depend on salmon fisheries, which is supported by release of hatching stock. The yield of common squid, sea cucumber, octopus, pink salmon and Pacific cod increased from period I to II by 38-fold, 367%, 64%, 48% and 37%, respectively.

Role of co-management in coastal fisheries

Unlike fisheries in modern countries, there is no centralized top-down management in traditional fisheries. When Japan was modernized during the second half of the 19th century, the country attempted to centralize the fisheries institution. However, these attempts resulted in a great deal of confusion and disturbance within fisheries societies; thus, Japan still has a decentralized co-management system involving fishers and the government. The transaction costs for fisheries management constitute one of the strongest arguments against top-down management systems. In the co-managed system, the costs for monitoring, enforcement, and compliance are shared between the government and local fishers and are remarkably lower than in systems with top-down regulation (Makino and Matsuda, 2005).

FCAs collected data on the amount of catch, catch area, and body size of catch, and they provided these data to prefectural research stations. Consequently, the local fishers voluntarily enlarged the mesh size of pollock gillnets from 91 to 95 mm in the 1990s. In 1995, the local fishers divided their fishing grounds into 34 areas based on local knowledge and then introduced a temporal fishing ban in seven of these areas. FCAs could pay these efforts to maintain their sustainable fisheries. After the stock of walleye pollock decreased, the fishers voluntarily added six more areas to the fishing ban in 2005. This is probably because the FCAs expected benefit of the World Heritage. These fishers annually re-examine the protected areas based on the scientific advice of the local research station. Clearly, local fishers often contribute considerable efforts toward consensus building in regard to voluntary regulations. Because the Nemuro stock of walleye pollock is also utilized by Russian fisheries, Rausu FCA needs to cooperate with Russian fishers and scientists.

Although the voluntary management procedure of the Rausu FCA is not well defined, they regulate the impact of fisheries in terms of recent stock conditions. The marine management plan for the Shiretoko site (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007) recognizes this feedback control as adaptive management. However, adaptive management must determine how to change its policy prior to the implementation of management.

Even in coastal fisheries, resources are not used by a single fisheries organization. Japanese coastal and offshore fishers and Russian trawl fishers exploit the walleye pollock in the Nemuro stock. Therefore, international cooperation is indispensable for the effective resource management of this species. As we mention below, the expansion of the Shiretoko World Heritage Site may be a good opportunity for the international management of walleye pollock.

Cull limit of Steller sea lions based on potential biological removal

The Okhotsk and Kurile populations of Steller sea lions migrate from their breeding and landing grounds in Russian waters to the waters surrounding Shiretoko for over-wintering and foraging. Because the Asian population of Steller sea lions sharply declined until the 1980s, this species is classified as endangered on the IUCN Red List. Fortunately, it has been gradually increasing at a rate of 1.2% per year since the early 1990s (Burkanov and Loughlin, 2005). The entire population size, which is spread throughout the Sea of Okhotsk, the western part of the Bering Sea, and the Komandorskie Islands, was estimated at 15,676 in 2005 by enumerating the reproductive colonies. In 2007, the JME ranked the sea lion as vulnerable (the third rank of threatened species).

Despite the threatened status of this species, sea lions are still culled by Japanese fishers because of the extensive damage caused to fishing nets, the extent of which increased during the 1980s (Fig. 4). When an international movement for the conservation of marine mammals began in the 1990s, the Hokkaido Fishing Coordination Commission established a cull limit of 116 sea lions per year. In 2007, the Fisheries Agency of Japan (JFA) recommended a revised cull limit based on the potential biological removal (PBR, Wade, 1998). The PBR is 120 determined by the number of migrant sea lions to Japanese waters and life history parameters used for the eastern Aleutian population (Angliss and Outlaw, 2007). An additional problem facing Steller sea lions is by-catch. For example, sea lions are often by-catch in bottom-set-net, gillnet, and set-net fisheries of Hokkaido Island. Unfortunately, there have been no reports of sea lion by-catch by these fisheries. According to informal interviews, the total number of by-catch was estimated between 55 and 107, the highest of which (107) was assumed for management purposes. The cull limit was revised based on the inferred number of by-catch from the PBR; thus, the revised cull limit is 120 (227 less 107) sea lions, which, until 2006, was nearly the same as the original cull limit. If the true number of by-catch is reported, the cull limit could be revised. Because we used the highest estimate for by-catch, the cull limit would likely increase, thus creating an incentive to compile a by-catch report.

Importance of cooperation with Russia in fisheries management

Sheppard (2005) documented the clear and apparent similarities between the environment and ecology of the Shiretoko Peninsula and the Kunashiri and Itrup Islands (Fig. 5). He also addressed the possibility for the future development of these regions as a more broad-scale "World Heritage Peace Park." Coastal fishers in the Shiretoko area are also concerned about the effects of Russian fisheries on the Nemuro stock of walleye pollock. Japan and Russia have been in conflict over the national boundary between the two countries since World War II. Russia (formerly the Soviet Union) actually occupied Habomai Shikotan, Kunashiri, and Itrup Islands, whereas Japan argued for inherent sovereignty of these islands. Despite these disagreements, UNESCO can register a world heritage site that is multi-national and includes a boundary under international dispute in accordance with the Convention on World Heritage. After the registration of the Shiretoko World Heritage Site, Japanese Prime Minister Shinzo Abe and Russian President Vladimir Putin agreed to organize scientific meetings for a cooperative effort in ecosystem conservation within the Sea of Okhotsk. Furthermore, if Japan and Russia agree to expand the Shiretoko World Heritage Site to southern Kurile and Urup Islands, the site will become an "international peace park" recommended by Sheppard (2005) based on mutual understanding and peace. In the first step, we share ecological data and knowledge between Japan and Russia.

Discussion

Scientists played a very important role during the registration process of the Shiretoko World Heritage Site by interpreting the evaluation and criticism of the IUCN to Japanese society. We propose a general procedure for environmental risk management (Rossberg et al., 2006), the key point of which is to devise a scientific procedure using consensus building among stakeholders. The purpose of management depends in part on all involved stakeholders (excluding the scientists). After a consensus concerning the objectives of management is reached, scientists can propose an action plan and numerical targets to achieve these goals.

The marine management plan at the Shiretoko site (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007) was accepted in 2007 by the Shiretoko World Natural Heritage Site Scientific Council and the Shiretoko World Natural Heritage Site Regional Liaison Committee. An English version was translated and published before the

UNESCO and IUCN inspection in February 2008. Coastal fisheries persist and exploit many species in the food web (Fig. 1) at the Shieretoko site and may function in this region like a top predator or an umbrella species. The catch statistics of fisheries (e.g., Fig. 2) can be used to determine the current status of marine food webs. However, it is too costly and virtually impossible for the government to monitor all details within an ecosystem. Therefore, the knowledge of fishers and data from fisheries activities should be fully utilized.

Matsuda et al. (2008) found that an economic rent-maximizing policy may lead to the convergence of target species and gear types and could provide information about very limited aspects of the ecosystem. These authors also used simple mathematical models of a multi-trophic level ecosystem to demonstrate that economically efficient fisheries would result in the loss of a significant fraction of the species in the ecosystem (Matsuda et al., 2008). In other words, economically efficient fisheries make sense for high fishery rents but not for sustaining total ecosystem services for society as a whole. One reasonable alternative to single species fisheries management is to conduct responsible fisheries that target a wide range of species using a variety of gear (Katsukawa and Matsuda 2003). As the Shiretoko case demonstrates, responsible and diverse fisheries operations can significantly contribute to the sustainability of ecosystem monitoring (Makino et al., 2008).

JFA surveys the stock status of walleye pollock and sea lions. In addition, Government of Japan and Hokkaido Prefectural Government (HPG) pay some additional effort for the world heritage, e.g., HPG supports scientists to survey upstream run of chum and pink salmons in two rivers and scientists evaluate the nutrient contribution from salmons to the terrestrial ecosystems. Taxon-specific catch and yield data are useful to evaluate the status of coastal fisheries and marine ecosystem. If both catch and price of some resource decrease, fishers pay attention to the status of these resources, such as greenling and sailfin sandfish. The Scientific Council recommended more conservation than persistence of the major salmon population, and a sufficient contribution of salmons from the sea.

Throughout the establishment of the marine management plan, fishers, scientists and environmental groups built trust and understood their sense of values. Scientists analyze and publish the status of coastal fisheries. This paper clarified some resources, walleye pollock, red king crab, rock fish (*Sebastes*) and greenling, under bad stock or economic conditions. In co-management, fishers will decide a conservation plan. Scientists can advise the fishers if scientists analyze both ecology and economy in the fisheries resources in the case of sand lance fisheries in Aichi Prefecture, Japan (Tomiyama et al. 2005).

Biodiversity may support the robustness of ecosystem processes against climate change and disasters. We typically investigate the value of ecosystem services under normal conditions; however, the value of biodiversity may be effective against unusual disasters. Japan has a rich biodiversity in comparison to other developed countries, potentially because it has geographic characteristics that have been resilient to past climate change. In future studies, we will further examine the value of biodiversity in Japan.

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Figure Legends

Fig. **1**. Catch statistics for ten major exploited taxa and total catch in the Shiretoko-daiichi, Utoro, and Rausu Fisheries Cooperative Associations (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007). Resource number is the order in the long-term average catch in Shiretoko site, as shown in Table 1 (12^{th} resource is sardine).

Fig. **2**. Proposed flow diagram for the Marine Management Plan of the Shiretoko World Heritage Site.

Fig. **3**. Catch statistics for Steller sea lions and damage to fisheries caused by sea lions in Hokkaido, Japan (Ohtaishi and Wada, 1999; Japan Fisheries Agency, 2007). Numbers of by-catch are not included or are not known.

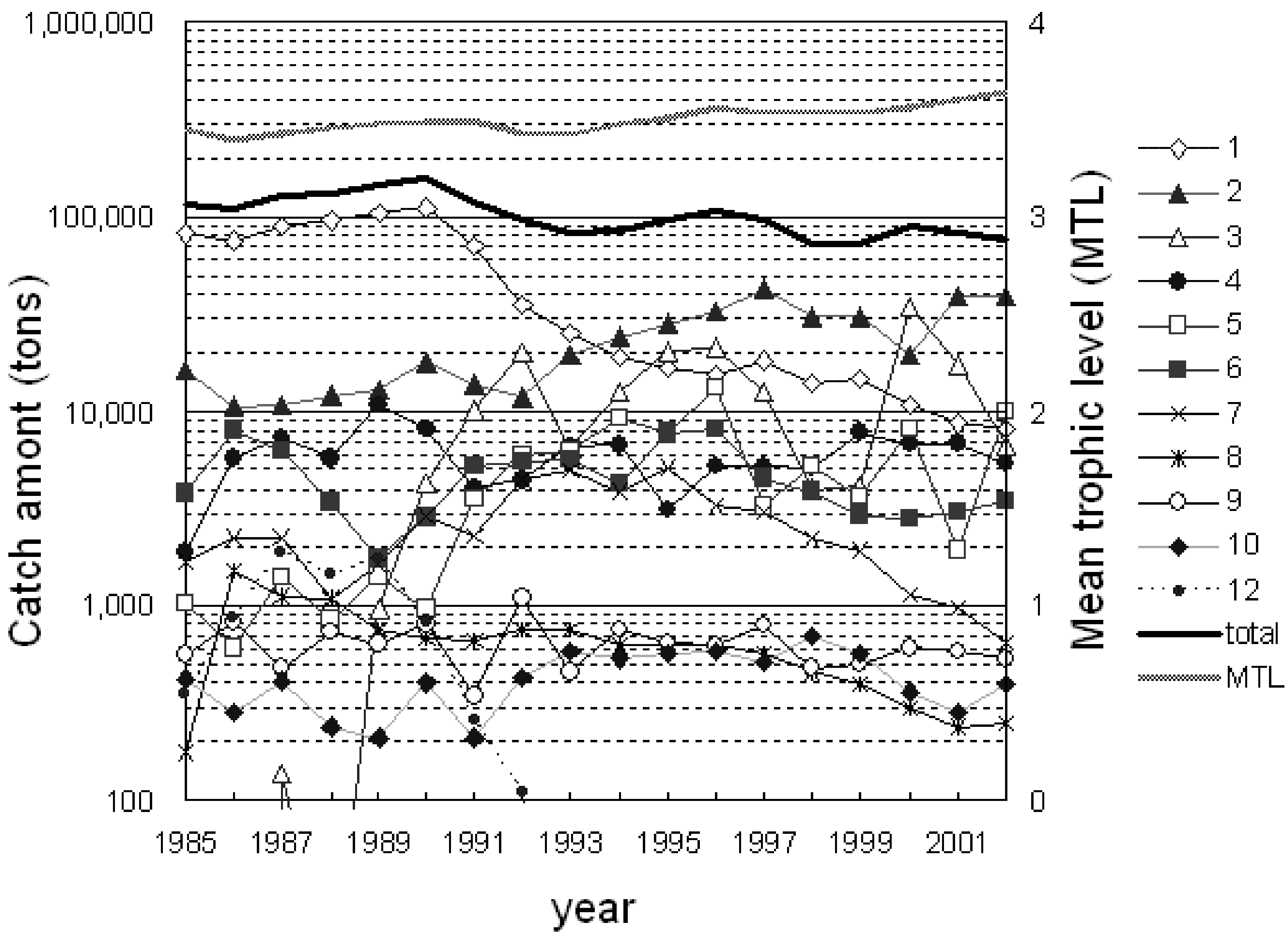
Fig. **4**. Present protected areas in the Shiretoko Peninsula of Hokkaido Island and Habomai, Shikotan, Kunashiri, Itrup, and Urup Islands, originally drawn by Mari Kobayashi. A national boundary between Japan and Russia exists between Hokkaido and Kunashiri and Habomai (as claimed by Russia) and between the Itrup and Urup Islands (as claimed by Japan).

Table 1. Annual catch and yield of major resources in Shiretoko site (Rausu, Shari and Utoro Fisheries Cooperative Associations) based on the long-term annual (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007). Orders and coefficient of variations in catch and yield are based on the long-term average throughout 1985-2002.

		Order in		Catch amount (ton)			Yield (thosand yen)			price (yen/kg)	
common name	academic name	catch	yield	1985-1989	1998-2002	C.V.	1985-1989	1998-2002	C.V.	1985-2002	1998-2002
chum salmon	*Oncorhynchus keta*	2	1	12,509	33,459	47%	6,660	8,466	23%	532	253
walleye pollock	*Theragra chalcogramma*	1	2	88,580	12,433	84%	11,063	1,846	78%	125	148
kelp	*Laminaria japonica*	9	3	648	586	27%	1,274	1,486	26%	1,967	2,534
common squid	*Todarodes pacificus*	3	4	225	13,182	100%	38	1,518	93%	170	115
rock fish	*Sebastolobus sp*	8	5	935	367	53%	1,318	947	35%	1,410	2,580
Pacific cod	*Gadus macrocephalus*	6	6	4,637	3,443	41%	662	905	38%	143	263
Okhostk atka mackerel	*Pleurogrammus azonus*	4	7	6,299	6,187	34%	810	805	23%	129	130
pink salmon	*Oncorhynchus gorbuscha*	5	8	1,060	5,362	80%	429	637	50%	405	119
sea urchin	*Strongylocentrotus intermedius*	26	9	48	35	34%	508	372	29%	10,591	10,711
scallop	*Patinopecten yessoensis*	7	10	1,767	1,665	53%	302	140	45%	171	84
octopus	*Octopus dolfleini*	10	11	313	471	34%	120	198	25%	384	420

Figure

Fig. 1



1,000,000
100,000
10,000
1,000
100
Catch amont (tons)
4
3
2
1
0
Mean trophic level (MTL)
1985
1987
1989
1991
1993
1995
1997
1999
2001
year
1
2
3
4
5
6
7
8
9
10
12
total
MTL

Fig. 2

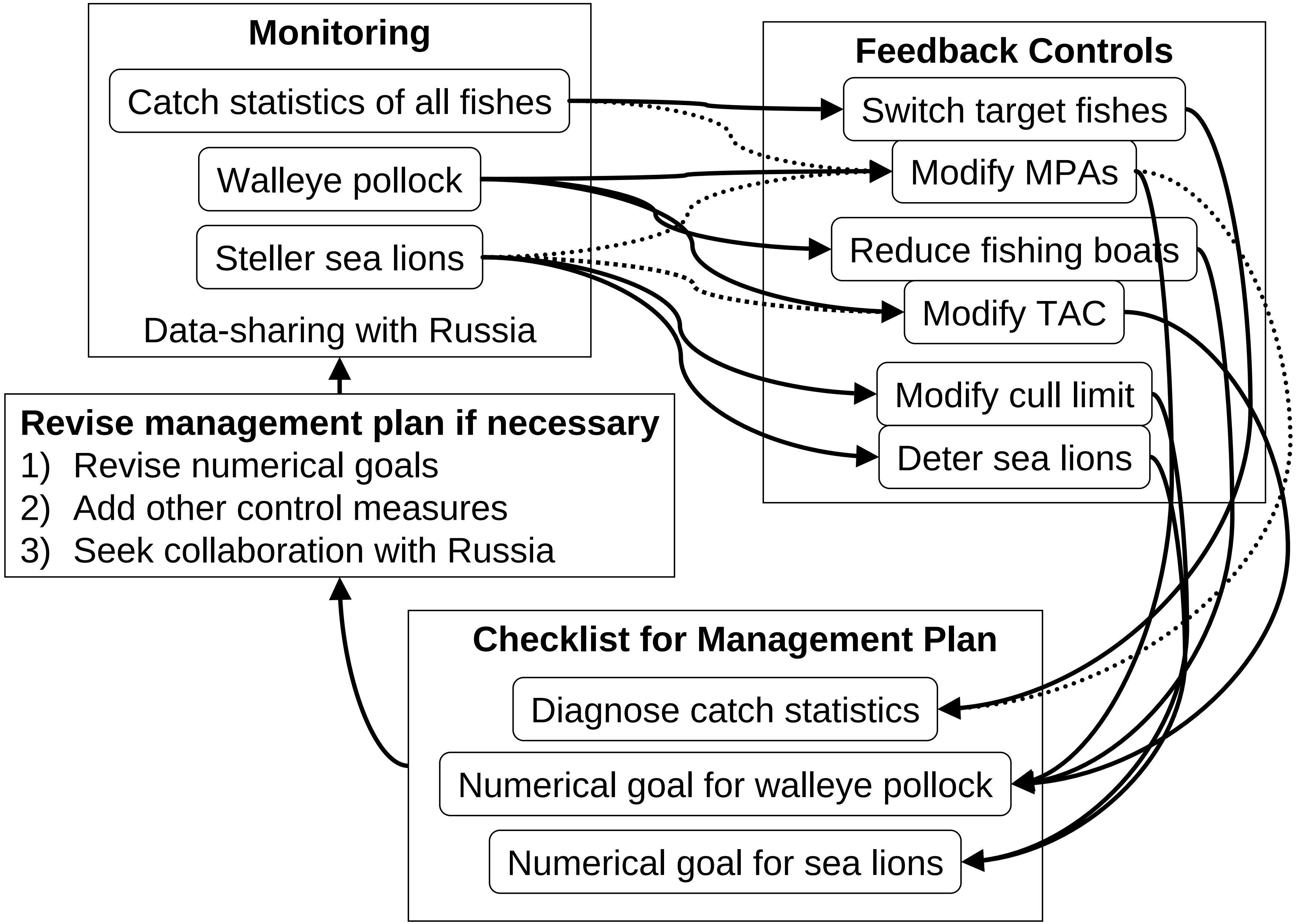
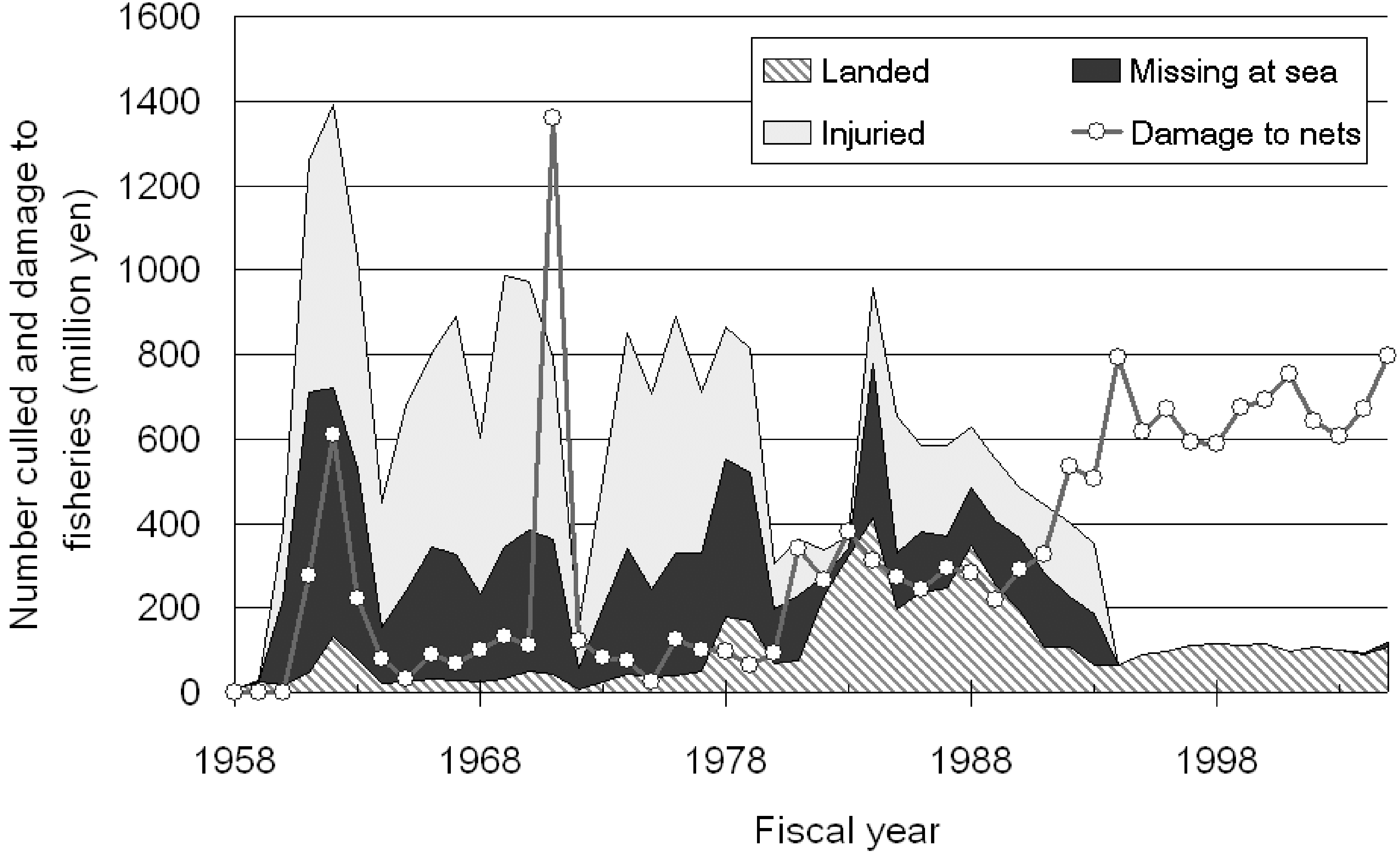
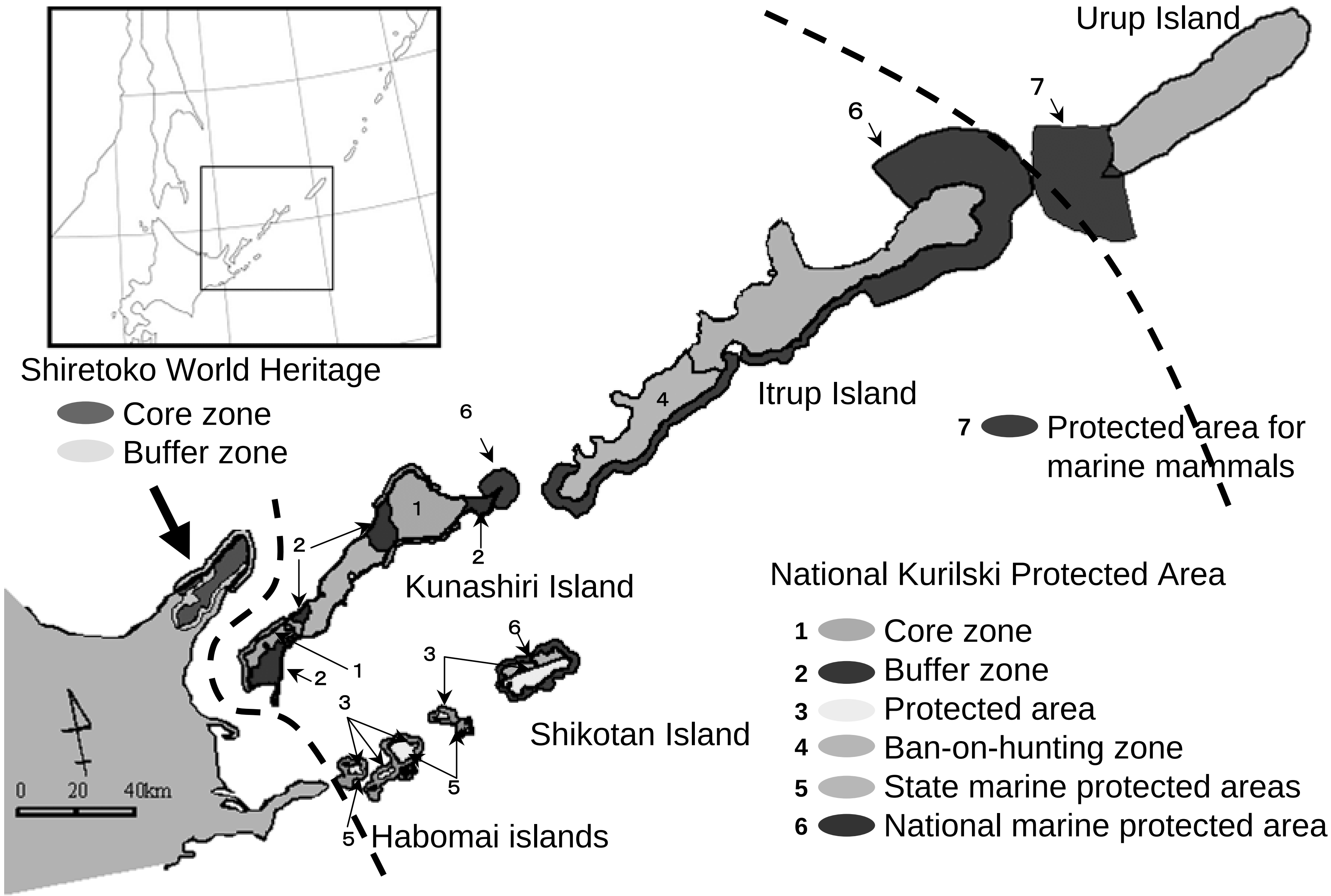

Monitoring
Catch statistics of all fishes
Walleye pollock
Steller sea lions
Data-sharing with Russia
Feedback Controls
Switch target fishes
Modify MPAs
Reduce fishing boats
Modify TAC
Modify cull limit
Deter sea lions
Revise management plan if necessary
1) Revise numerical goals
2) Add other control measures
3) Seek collaboration with Russia
Checklist for Management Plan
Diagnose catch statistics
Numerical goal for walleye pollock
Numerical goal for sea lions

Fig. 3



Landed
Missing at sea
Injuried
Damage to nets
1600
1400
1200
1000
800
600
400
200
0
1958
1968
1978
1988
1998
Number culled and damage to fisheries (million yen)
Fiscal year

Fig. 4



Urup Island
7
6
Itrup Island
4
7
Protected area for
marine mammals
Shiretoko World Heritage
Core zone
Buffer zone
6
1
2
2
Kunashiri Island
2
1
2
National Kurilski Protected Area
6
3
3
5
Shikotan Island
5
Habomai islands
0 20 40km
1 Core zone
2 Buffer zone
3 Protected area
4 Ban-on-hunting zone
5 State marine protected areas
6 National marine protected area