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Title	Development of an adaptive marine ecosystem management and co-management plan at the Shiretoko World Natural Heritage Site
Author(s)	Matsuda, Hiroyuki; Makino, Mitsutaku; Sakurai, Yasunori
Citation	Biological Conservation, 142(9), 1937-1942 https://doi.org/10.1016/j.biocon.2009.03.017
Issue Date	2009-09
Doc URL	https://hdl.handle.net/2115/39325
Type	journal article
File Information	BC142-9_p1937-1942.pdf



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

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21 Word count = 4610 (including cover page)

22

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

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.

44

45 **Introduction**

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

50 Marine management in Japan is characterized by a long history of coastal co-management
51 of fishers' organizations (Makino et al., 2008). Co-management is defined as the sharing of
52 responsibilities between governmental institutions and groups of resource users (Persoon et al.,
53 2005). In many countries environmental management is reformulated from exclusive state control
54 to various kinds of joint management in which local communities, indigenous peoples, and
55 nongovernmental organizations share authority and benefits with governmental institutions.
56 Fisheries in Japan face several important challenges, e.g., (i) exclusive use by fisherman with
57 fishery rights/licenses (there are few exceptions for free-fisheries and recreational angling), (ii) lack
58 of full transparency in management procedures, and (iii) lack of objective benchmarks or numerical
59 goals in management plans. Here, we elaborate on the characteristics and issues facing the
60 management of marine ecosystems in Japan. We use the "Multiple-Use Integrated Marine
61 Management Plan for the Shiretoko World Natural Heritage Site, Japan" (Ministry of the
62 Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007), as a case
63 study of adaptive marine ecosystem management and co-management of coastal fisheries.

64 The natural resource management plan of the Shiretoko site is characterized by
65 transparency and consensus building, because (i) UNESCO and IUCN require that the plan be
66 sustainable; and (ii) the Government of Japan has guaranteed local fisheries that there will be no
67 additional regulations included in the plan. These "constraints" seemed to be incompatible with
68 each other. In this paper, we show the solution of these constraints. The solution will characterize
69 Japanese fisheries. In addition, we will present a method to analyze the sustainability from fisheries
70 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

98 present Marine Management Plan for the Shiretoko site (Ministry of the Environment, the
 99 Government of Japan, and Hokkaido Prefectural Government, 2007) does not include any
 100 thresholds or numerical goals for its indicator species, which are currently only monitored. A
 101 crucial short-term goal will be to establish such thresholds and/or numerical goals for these
 102 indicator species.

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

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

121 If some categories of fisheries resources decrease in stock and/or catch, we recommend
 122 target switching from the decreased resource to another resource that is temporally abundant
 123 (Katsukawa and Matsuda 2003). If all major fisheries resources decrease, the extension or
 124 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 (Tomiya 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).

140

141 **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 salmon. 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

152 crab (*Paralithodes camtschaticus*), *Sebastes* and herring (*Clupea pallasii*) substantially decreased
 153 by 100%, 99.4%, 99%, 97% and 96%, respectively. Sardine (Watanabe et al. 1995), anchovy and
 154 herring decreased probably because of natural fluctuation in Japanese waters, while we do not
 155 know the reason why red crab king and *Sebastes* decreased. Greenling (*Hexagrammos otakii*)
 156 decreased their catch by 70% and the fish price by 64% from period I to II.

157 There are two major resources in Shiretoko site, chum salmon and walleye pollock. Those
 158 were two of largest-yield resource throughout 1985-2002, except in 1996, 97 and 2001 while the 2nd
 159 largest yield resource was common squid in 1996, 97 and kelp in 2001 . The largest yield resource
 160 was walleye pollock during 1985-92 and chum salmon during 1993-2002. Common squid, kelp,
 161 rock fish, *Sebastes* and Pacific cod have at least once been the 3rd largest yield throughout
 162 1985-2002. Sum of the top three largest yield resource ranged from 81% in 1985 to 53% in 1996 of
 163 the total annual yield. Since walleye pollock decreased in 1991, Shiretoko fisheries now depend on
 164 salmon fisheries, which is supported by **release of hatching stock**. The yield of common squid, sea
 165 cucumber, octopus, pink salmon and Pacific cod increased from period I to II by 38-fold, 367%,
 166 64%, 48% and 37%, respectively.

167

168 **Role of co-management in coastal fisheries**

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

178 FCAs collected data on the amount of catch, catch area, and body size of catch, and they

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

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

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

201

202 *Cull limit of Steller sea lions based on potential biological removal*

203 The Okhotsk and Kurile populations of Steller sea lions migrate from their breeding and
 204 landing grounds in Russian waters to the waters surrounding Shiretoko for over-wintering and
 205 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.

229

230 *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

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

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

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

286 Throughout the establishment of the marine management plan, fishers, scientists and

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

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

299 300 **Acknowledgments**

301 We thank Drs. H. Homma, Y. Kagami, M. Kobayashi, Y. Maruyama, Y. Ohtaishi, S. Oyamada, M.
 302 Sano, anonymous reviewers, Professros R. Primack and H. Higuchi for their valuable comments on
 303 the earlier version of the manuscript. We also thank the members, secretary, and observers of
 304 Marine Working Group of the Shiretoko World Heritage Site. This work was supported in part by
 305 the Pew Fellowship grant and the Global COE Program “Eco-Risk Asia” at Yokohama National
 306 University to H.M.

307 308 **References**

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- 352
- 353

354 No tables in this manuscript

355

356 Figure Legends

357

358

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

363

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

366

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

370

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

375

376 Table 1. Annual catch and yield of major resources in Shiretoko site (Rausu, Shari and Utoro Fisheries Cooperative Associations) based on the long-term
377 annual (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007). Orders and coefficient of variations in catch and
378 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	<i>Oncorhynchus keta</i>	2	1	12,509	33,459	47%	6,660	8,466	23%	532	253
walleye pollock	<i>Theragra chalcogramma</i>	1	2	88,580	12,433	84%	11,063	1,846	78%	125	148
kelp	<i>Laminaria japonica</i>	9	3	648	586	27%	1,274	1,486	26%	1,967	2,534
common squid	<i>Todarodes pacificus</i>	3	4	225	13,182	100%	38	1,518	93%	170	115
rock fish	<i>Sebastolobus sp</i>	8	5	935	367	53%	1,318	947	35%	1,410	2,580
Pacific cod	<i>Gadus macrocephalus</i>	6	6	4,637	3,443	41%	662	905	38%	143	263
Okhostk atka mackerel	<i>Pleurogrammus azonus</i>	4	7	6,299	6,187	34%	810	805	23%	129	130
pink salmon	<i>Oncorhynchus gorbuscha</i>	5	8	1,060	5,362	80%	429	637	50%	405	119
sea urchin	<i>Strongylocentrotus intermedius</i>	26	9	48	35	34%	508	372	29%	10,591	10,711
scallop	<i>Patinopecten yessoensis</i>	7	10	1,767	1,665	53%	302	140	45%	171	84
octopus	<i>Octopus dofleini</i>	10	11	313	471	34%	120	198	25%	384	420

Fig. 1

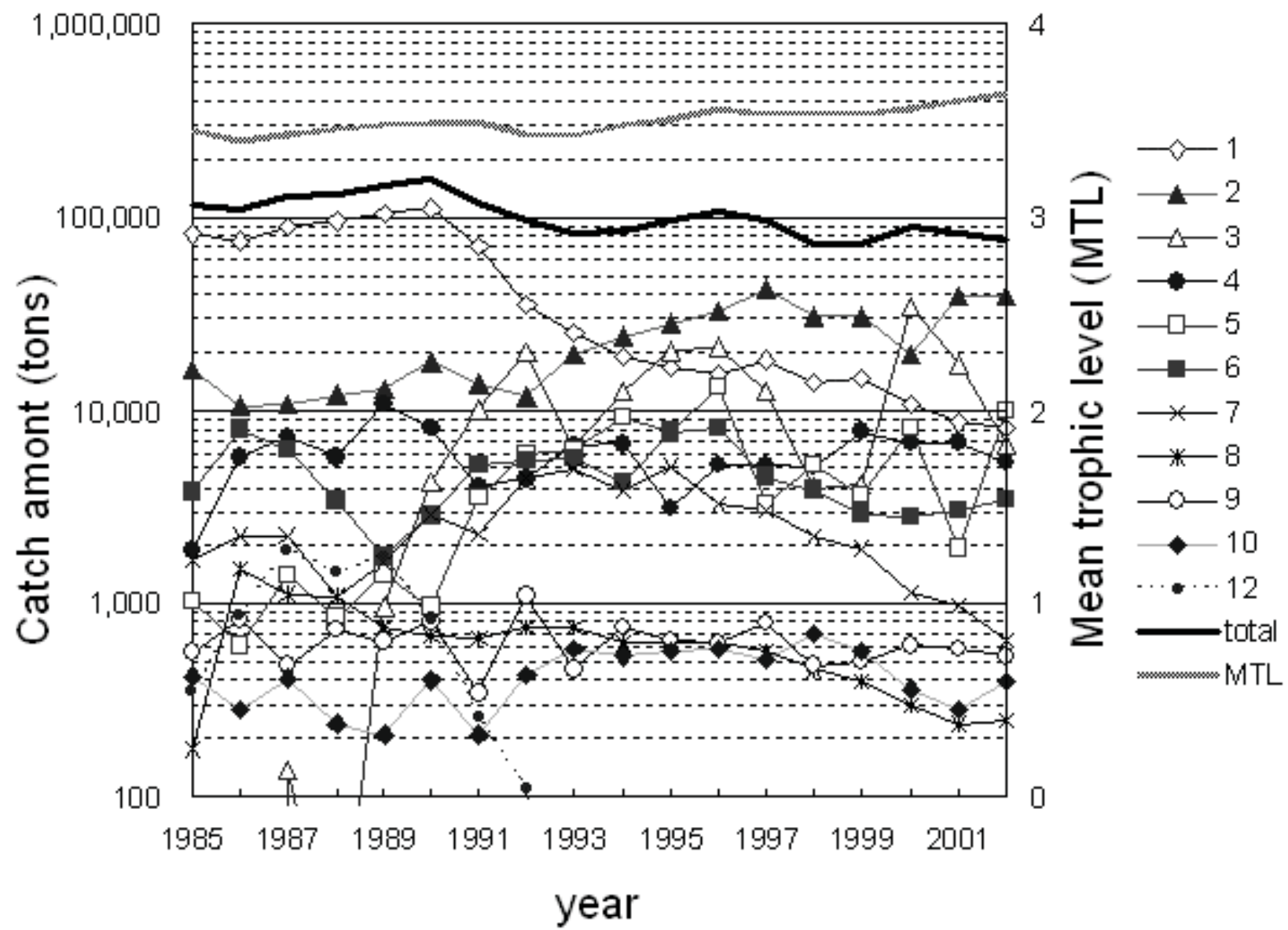


Fig. 2

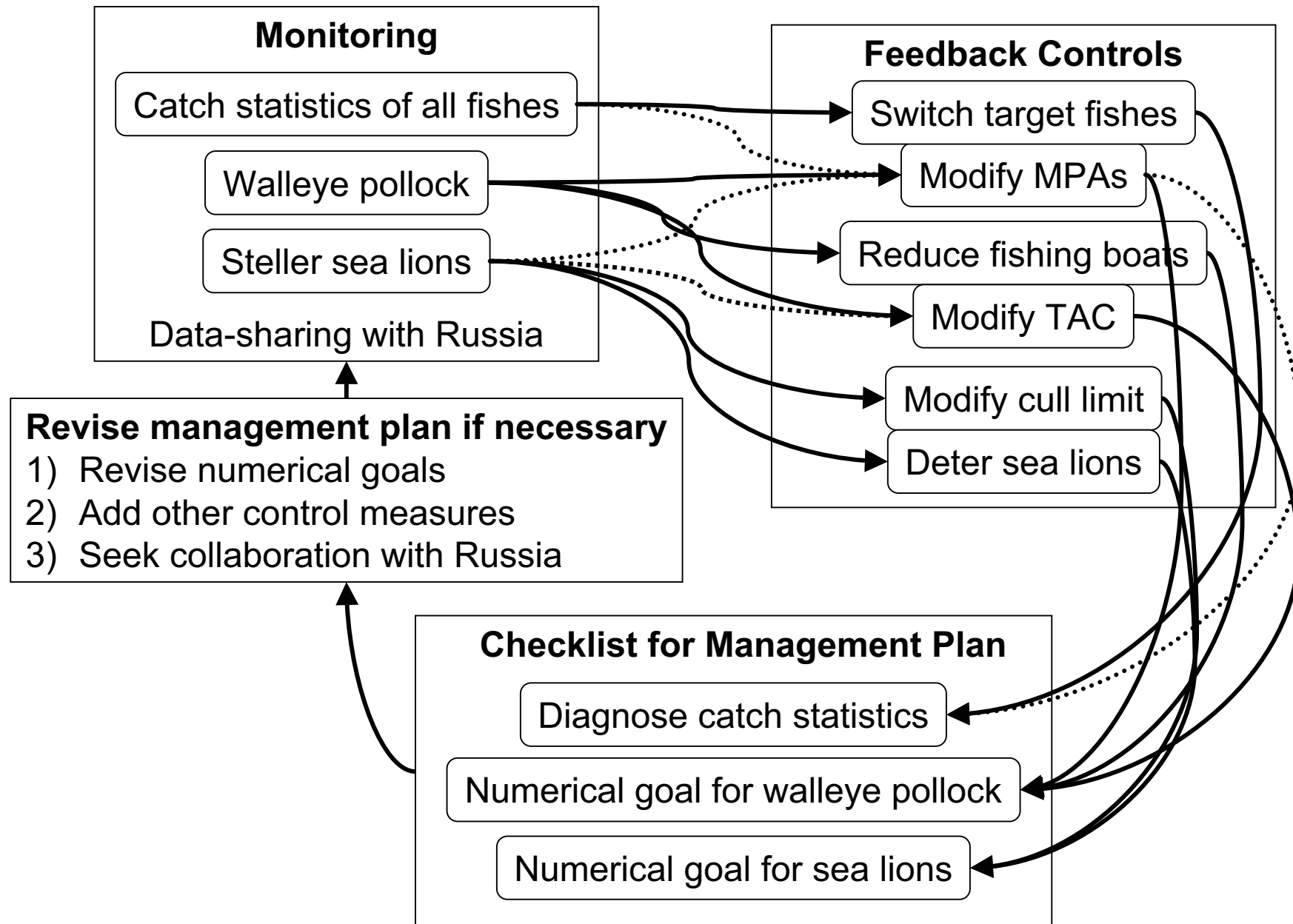


Fig. 3

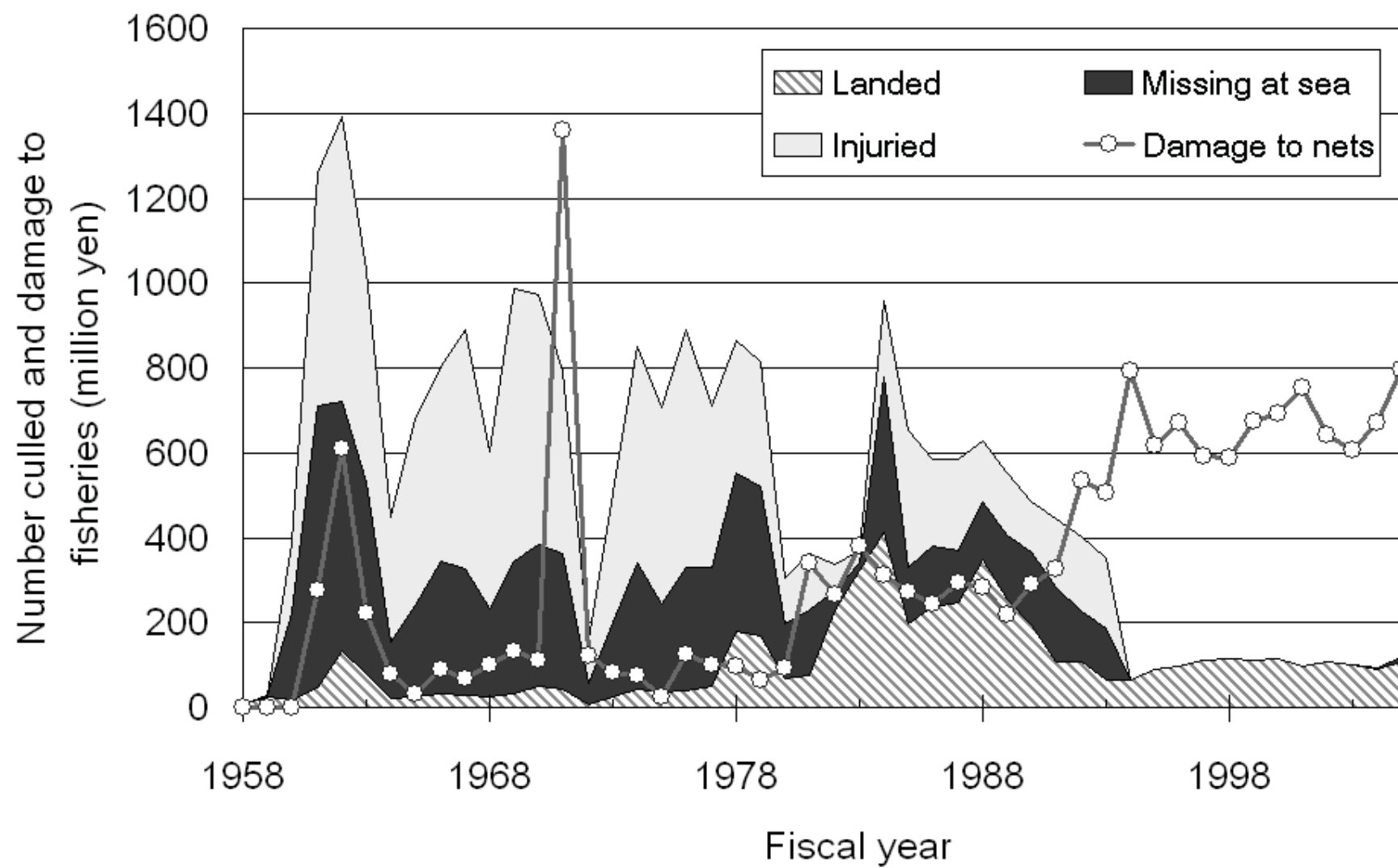


Fig. 4

