Matsuda H (in press) 3-6 Risk and resource management. Mitsuru Osaki, A. Braimoh, K. Nakagami, O. Saito (eds) "Designing Our Future from Local and Regional perspectives - Bioproduction, Ecosystems & Humanity" :

5-5 Risk and resource management

Hiroyuki Matsuda

5-5-1 Theory of maximum sustainable ecosystem services

Although we focused on the fisheries yield in the previous section, ecosystems give us a variety of benefits (World Resource Institute 2005: 137). Harvests from agriculture, forestry and fisheries are just a small part of the ecosystem services (Costanza et al. 1997: 253-260). Ecosystem services include support services such as soil formation, photosynthesis and nutrient cycling; provisioning services such as food, water, timber and fiber; regulating services that affect climate, floods, disease, waste and water quality; and cultural services that provide recreational, aesthetic and spiritual benefits (World Resource Institute 2005: 137). The yield of fisheries belongs to provisioning services. The existence of bio-resources may maintain these services.

There are some criticisms against the theory of maximum sustainable yield (MSY) (Matsuda and Abrams 2008: 737–744). The MSY fishing policy does not reflect uncertainty in stock estimates (measurement errors) and in the relationship between the spawning stock and recruitment (process uncertainties). The MSY policy also ignores complexity in ecosystem processes because the theory uses single stock dynamic models (Matsuda and Katsukawa 2002: 366–370). Hiroyuki Matsuda and Peter Abrams (2006: 225–237) analysed the maximum sustainable yield from entire food webs with independent fishing efforts on each species. They concluded that MSY policy does not guarantee the co-existence of species, and they proposed the concept of ‘constrained MSY’ that maximises the sustainable yield under which all species could co-exist. Matsuda et al. (2008: 737–744) incorporated ecosystem service into an optimal fisheries policy, and they called the optimal policy that maximises the total ecosystem services the maximum sustainable ecosystem service (MSES). Ecosystem services other than fisheries yield likely depends on the standing biomass, while the fisheries yield depends on the catch amount. The standing biomass probably monotonically decreases as the fishing effort increases, while the fisheries yield is a unimodal function of the fishing effort.

Suppose the fisheries yield $Y(C)$ from a single target species as an increasing function of the catch amount C, the cost of fisheries $k(E)$ as an increasing function of the fishing effort E, and the ecosystem service other than fisheries yield $S(N)$ as an increasing function of the standing biomass N. The total ecosystem service V is written as a function of N and C.

(1) $V(N, C) = Y(C) - k(E) + S(N)$

Hereafter, we simply call $S(N)$ the utility of standing biomass. The catch amount C is an increasing function of both the fishing effort E and the stock biomass N.

We assume the following fish stock dynamics :

(2) $dN/dt = f(N)N - C(E,N)$,

where t is an arbitrary time unit and $f(N)$ is the per capita reproduction rate. $f(N)$ is a decreasing function of N due to the density effect, and $f(N)N$ is usually a unimodal function of N. In these equations, we ignore process uncertainty in $f(N)$ and implementation errors in $C(E,N)$.

We can obtain the equilibrium point denoted by N^* that satisfies $dN/dt = 0$ in eqn (2). The equilibrium point N^* depends on E. In general, the stable equilibrium point decreases as the fishing effort increases. This is intuitively understandable. The utility of standing biomass, $S(N)$, is likely a convex or sigmoid curve because the utility likely saturates when the stock is sufficiently abundant. In the first step, we obtain the optimal fishing effort that maximises the total ecosystem service $V(N,C)$ given by (1) at the equilibrium, denoted by V^*. Since N^* and C^* are the function of E, the total ecosystem service at the equilibrium is a function of E.

We consider the optimal fishing effort that maximises V^*. Matsuda et al. (2008: 737–744) called V^* the maximum sustainable ecosystem service (MSES) and denoted the fishing effort for MSES by E_{MSES}. If we ignore the utility of the standing biomass $S(N)$, as is usually assumed in classical fisheries theory, V^* is a unimodal function of E and the optimal fishing effort, denoted by E_{MEY}, is well known by the maximum economic yield (MEY). If the cost of fisheries is negligible ($k(E) = 0$), E_{MEY} becomes the effort at the maximum sustainable yield (MSY), denoted by E_{MSY}.

If $S(N)$ is an increasing function of N, the E_{MSES} is always smaller than the E_{MSY} and E_{MEY}. However, the distance between E_{MSES} and E_{MEY} depends on the magnitude and curvature of S(N). The E_{MSES} is smaller when the derivative of utility of standing resource with respect to the stock is at a larger magnitude (dS/dN is larger). If $|dS^*/dE| > dY^*/dE - dk/dE$ at $E = 0$, dV^*/dE is negative at $E = 0$ and the fishing ban can be optimal.

The fishing effort for actual fisheries is often considered to be larger than E_{MSY} , and it is unsustainable. Classical fisheries science recommends MSY or MEY. Recently, marine ecologists recommended a no-take zone for ecosystem-based management (Pikitch et al. 2004: 346–347). The fishing effort for a maximum sustainable ecosystem service is between the fishing ban and E_{MEY} (Figure 1.1). A paradigm shift is needed to encourage environment-friendly fisheries (Castilla and Defeo 2005: 1324–1325).

Adaptive management predicts and monitors changes in the ecosystem, and subsequently reviews and adjusts the management and use of natural resources. 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.

5-5-2 Magnitude of fisheries' impact on marine ecosystems

The history of fisheries is characterised by overfishing (Hannesson 1996: 160). The theory of MSY takes into account the long-term yield from a living marine resource. This theory explicitly assumes a negative relationship between yield and standing stock abundance. In addition, marine ecosystems are characterised by uncertainty, dynamic properties and complexity. However, the classical MSY theory does not include any of these factors. Thus, it is not surprising that the MSY theory and its derivatives have not worked for fisheries management (Matsuda and Abrams 2008: 737–744).

Instead of a theory of single species management, an ecosystem approach has been popular. Matsuda and Abrams (2008: 737–744) made eleven recommendations that could both increase the food resources derived from fish and reduce the chances of overexploitation or extinction: (1) catch fish at lower trophic levels; (2) do not use fish as fish meal; (3) reduce discards before and after landings; (4) establish food markets for temporally fluctuating fishes at lower trophic levels; (5) improve the food-processing technology used on small pelagic fishes; (6) switch the target fish to correspond to the temporally dominant species; (7) conserve immature fish, especially when the species is at a low stock level; (8) develop technologies for selective fishing; (9) conserve both fish and fisheries; (10) say goodbye to traditional MSY theory and (11) monitor not only the target stock level but also any other indicator of the 'entire' ecosystem.

There are many warnings in marine ecosystems. Pauly et al. (2002: 320) calculated the mean trophic level of fisheries catch (MTL) and showed that the MTL decreased from ca. 3.5 in 1950 to ca. 3.3 in 1990 (Figure 2.1a). This conclusion implies overfishing because the fish being harvested are increasingly coming from the less valuable lower trophic levels as populations of higher trophic level species are depleted. The Convention on Biological Diversity chooses the mean trophic level of marine fisheries catch as an indicator of marine ecosystem integrity and ecosystem goods and services (Secretariat of Convention on Biological Diversity, 2006: 1-81). Pauly et al. (2002: 320) called the decline of the MTL 'fishing down'. Ransom Myers and Boris Worm (2003: 280–283) argued that the biomass of top predators, including tuna, has been reduced by 90% relative to levels prior to the onset of industrial fishing. In addition, Jean-Jacques Maguire et al. (2006: 96) noted that about 3/4 of stocks are either fully exploited or overexploited.

Despite these warnings, there is some criticism of these arguments. The magnitude of tuna stock decline estimated by Myers and Worm (2003: 280–283) is an overestimation (Hampton et al. 2005: E1–E2). Although the southern bluefin tuna (*Thunnus maccoi*, SBT) is ranked on the critically endangered list by the International Union for Conservation of Nature (IUCN), the extinction risk of SBT is definitely smaller than that of the blue whale that is ranked endangered. It is very unlikely that SBT will become extinct within the next 50 years (Matsuda et al. 1998: 271–278), while it is again difficult to satisfy the target of recovering spawning stock biomass to the 1980 level by 2020 by the Commission for the Conservation of Southern Bluefin Tuna (Mori et al. 2001: 125–132).

The MTL of the global marine landings did not show a monotonic decline, but rather fluctuated from decade to decade (see Figure 3.3 of MA 2005). The global MTL was low around 1970 and the 1980s, while catches of Peruvian anchovy and Japanese sardine were large, respectively. The theory of 'Fishing Down' is based on the assumption that the major target species is a high-price and higher trophic level fish. This belief is not true everywhere. The proportion of low-value fish of the total fish consumption is ca. 80% in developing countries, while it is ca. 10% in developed countries (Delgado et al. 2003: E1–E2). In Japan, the MTL was ca. 3.6 in 1960, ca. 3.1 in 1990 and ca. 3.6 in 2000. Therefore, Japanese fishery is characterised by a higher MTL than the world average, and its MTL has not shown a long-term decline (Figure 2.1b). However, there are several cases of overfishing and failure of stock management in Japan (Kawai et al. 2002: 961–969).

It should be noted, however, that although the total landings of demersal fishes had reached a plateau by the 1970s, those of pelagic fishes increased until the late 1980s. Some of these pelagic fish species have naturally fluctuated greatly in stock abundance, even without fisheries for several thousand years (Baumgartner et al. 1992: 24–40). The collapse of Japanese sardine in the 1990s was almost certainly caused by a natural variation in the environment (Watanabe et al. 1995: 1609–1616). When the stock is at a low level, the impact of fisheries on pelagic fishes prevents the stock from recovering (Kawai et al. 2002: 961–969).

There is a mismatch between demand and supply of fisheries resources from the food security viewpoint. In the case of Japanese fisheries, the total allowable catch (TAC) exceeded the allowable biological catch (ABC) in some fish, including sardine, and the actual catch exceeded ABC in some years (Figure 2.2a). In contrast, the actual catch is much smaller than the ABC in some species, including Pacific saury and anchovy. It should be noted that the total ABCs of these species is larger than 2 million tons (Figure 2.2b). However, economic demand for these species is low in Japan, while economic demand of overfishing species, including tuna and chub mackerel, is still high, partly because of overcapitalisation of fishing vessels and a stiff market. The Japanese, however, do not use jellyfish despite the fact that it frequently occupies the Japanese coastal regions and the Chinese eat it.

5-5-3 Fisheries co-management in Shiretoko World Heritage

Marine management in Japan is characterised by (i) seeking a balance between sustainable use and ecosystem conservation and (ii) involving the co-management of fishers' organisations (Makino et al. 2008: 207-214). Co-management is defined as the sharing of responsibilities between governmental institutions and groups of resource users (Persoon et al. 2005: 320). In many countries, environmental management is reformulated from exclusive state control to various kinds of joint management in which local communities, indigenous peoples and non-governmental organisations share authority and benefits with governmental institutions. Fisheries in Japan face several important challenges, e.g. (i) exclusive use by fisherman with fishery rights/licences (there are a few exceptions for free fisheries and recreational angling), (ii) lack of full transparency in management procedures, (iii) lack of objective benchmarks or numerical goals in management plans, and (iv) strong dependence on political pressure from abroad (Matsuda et al. 2009: 1937-1942). Matsuda et al. (2009) reported these characteristics to explain why coastal fisheries exist at the Shiretoko World Heritage site.

Shiretoko was registered as the third World Natural Heritage site in Japan because of its (i) formation of seasonal sea ice at some of the lowest latitudes in the world; and (ii) high biodiversity and many globally threatened species. United Nations Educational, Scientific and Cultural Organization and IUCN required the natural resource management plan of the Shiretoko site to be sustainable, while the national government of Japan guaranteed that no additional regulations were included in the plan.

The Japan Ministry of Environment (JME) organised a Scientific Council (SC) to draft a proposal nominating Shiretoko as a World Natural Heritage candidate. The proposal was reviewed by the IUCN. IUCN then sent a letter dated 20 August 2004 to the Japanese government recommending an increase in the level of conservation of marine waters and an investigation of the effects of dams on wild populations of salmonids. We refer here to this document as 'the first IUCN letter'. It was not until a local newspaper revealed the existence of this letter that the government of Japan had notified the SC of the receipt of the letter. The Japanese government did not call a meeting of the SC to discuss the letter; however, the SC voluntary compiled a document advising the Japanese government on how to respond to the first IUCN letter. This step was probably taken because the SC members recognised that this review process was historically important to establish scientific council activity for future nature conservation or restoration projects in Japan. The SC recommended additional, essential mitigation of river structures, further marine conservation efforts and the formation of marine and river structure working groups. The JME ignored this advice and replied that further regulations of the walleye pollock fisheries were unnecessary.

IUCN sent another letter dated 2 February 2005 to the JME and explicitly requested the expansion of the marine registered area and an expedited marine management plan. We refer to this document as ‘the second letter’. After this letter was received, the JME convened the members of the SC, which compiled its recommendations and formed two working groups: the Marine Working Group (hereinafter, Marine WG) and the River Structure Working Group. The Marine WG included several SC members and other fisheries scientists, and the Marine WG invited members of regional fisheries co-operative associations (FCAs) as observers.

Officials from the Ministry of the Environment, the government of Japan, and the Hokkaido prefectural government rejected the possibility of future fisheries regulations at the Shiretoko site. The SC acknowledged the conventional efforts of fishers to voluntarily regulate their fishing efforts, and the FCAs agreed to the expansion of the heritage area without any top-down regulation (Makino et al. 2008: 207-214).

In accordance with the advice of the SC, the JME replied to the IUCN and agreed to the major points of the second letter. In addition, the Rausu FCA voluntarily expanded the seasonal fishing-ban area for the 2005 fishing season (Figure 3.1). The contribution of fishers to the review process for the Shiretoko World Heritage Site was indispensable, because they were the only group to satisfy the requests of the IUCN and UNESCO to increase the level of conservation of marine ecosystems. UNESCO registered Shiretoko as a World Natural Heritage site in 2005.

The adaptive management plan involves voluntary activities by local resource users that are suitable for use within a local context, flexible to ecological and social fluctuations and can be efficiently implemented by increased legitimacy and compliance. Such an approach is suitable for developing coastal countries where a large number of artisanal fishers catch a variety of species using various types of gear.

The objective of the ‘Multiple-Use Integrated Marine Management Plan’ formulated by the Ministry of the Environment, the government of Japan, and the Hokkaido prefectural government (see Matsuda et al. 2009: 1937-1942) 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. The target area of this plan is the marine component that extends up to 3 km from the coastline. The premise of the Plan involves legal restrictions relating to the conservation of the marine environment, marine ecosystems and fisheries, as well as voluntary restrictions on marine recreation and community-based marine resource management carried out by fishers.

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 management plan details the vast food web structure of the Shiretoko site (Figure 3.2) and includes fisheries yields for ten categories of major fisheries resources (Figure 3.3). 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 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 MSY policy for the entire ecosystem does not guarantee the co-existence of all species (Matsuda and Abrams 2006: 225–237). Therefore, the goal of the management plan is twofold: sustainable fisheries and biodiversity conservation. Ecosystem-based fisheries management can use some data from fisheries, such as catch amount and its distribution, catch per unit effort, age structure of harvest, and by-catch data of non-target species. We need to monitor information on unused fish and oceanographic information gathered by those individuals other than fishers, usually government authorities. We need to know fisheries' impact on ecosystem processes. For example, fisheries may have a negative impact on Steller sea lions, because walleye pollock is a target species of fisheries, which is eaten by sea lions. Steller sea lions are a threatened species and are important from a conservation viewpoint. These species are controllable by several conservation measures (Matsuda et al. 2009: 1937-1942).

If major fisheries resources decrease, these stocks should be conserved and the target resource should be changed. In the Shiretoko area, the target species was changed from walleye pollock to chum salmon in the early 1990s. The target switching in fisheries is effective in multispecies fisheries management (Matsuda and Katsukawa 2002: 366-370). In addition, the fishing-ban area of walleye pollock changed with the stock abundance in 1995 and 2005 (Figure 3.1).

Unlike fisheries in modern countries, there is no centralised, top-down management in traditional fisheries. Although Japan was modernised in the second half of the 19th century, the country still has a decentralised, co-management system involving fishers and the government. There are many artisanal fishers in Japan (Makino and Matsuda in press). The transaction cost for fisheries management is one of the strongest arguments against top-down management systems. The costs for monitoring, enforcement and compliance can be shared between the government and local fishers in a co-managed system (Makino and Matsuda 2005: 441–450).

5-5-4 Conclusion

I introduced possible future perspectives on sustainable ecosystem services that offer a possible alternative theory of sustainable fisheries yield. I also discussed modern fisheries management and co-management theory. The Japanese use many types of fisheries resources. The mean trophic level of Japanese fisheries is much higher than the world average, and it did not decrease. The MTL has shortcomings as an indicator of overfishing. The potential availability of fisheries resources in the Japanese Exclusive Economic Zone is still large, while Pacific saury and anchovy are not sufficiently used. This suggests that the warning by the world fisheries does not reflect the degradation of the marine ecosystem, but rather is caused by a mismatch between supply and demand of fish species. The validity of co-management in Japanese coastal fisheries worked well, at least in the Shiretoko World Heritage site. All of these different circumstances suggest new insights into sustainable fisheries.

5-5-5 Acknowledgments

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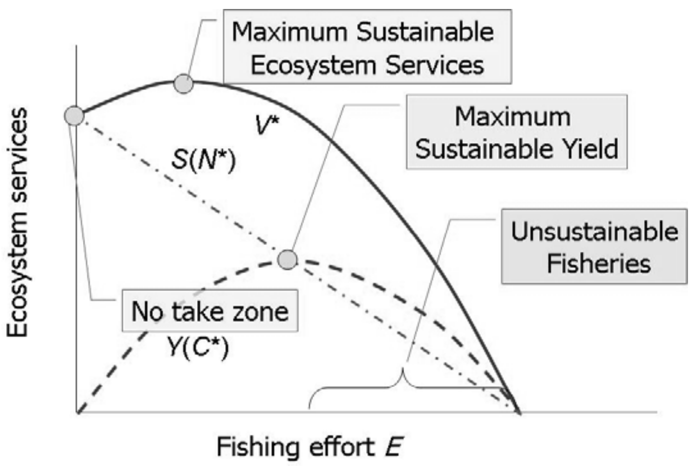

Figure 1.1 Schematic relationship between overfishing, maximum sustainable yield, maximum sustainable ecosystem services and no-take zone. Dotted line, broken curve and bold curve represent the utility of standing biomass (S(N*)), fisheries yield (Y(C*)) and the total ecosystem services (V*), respectively.

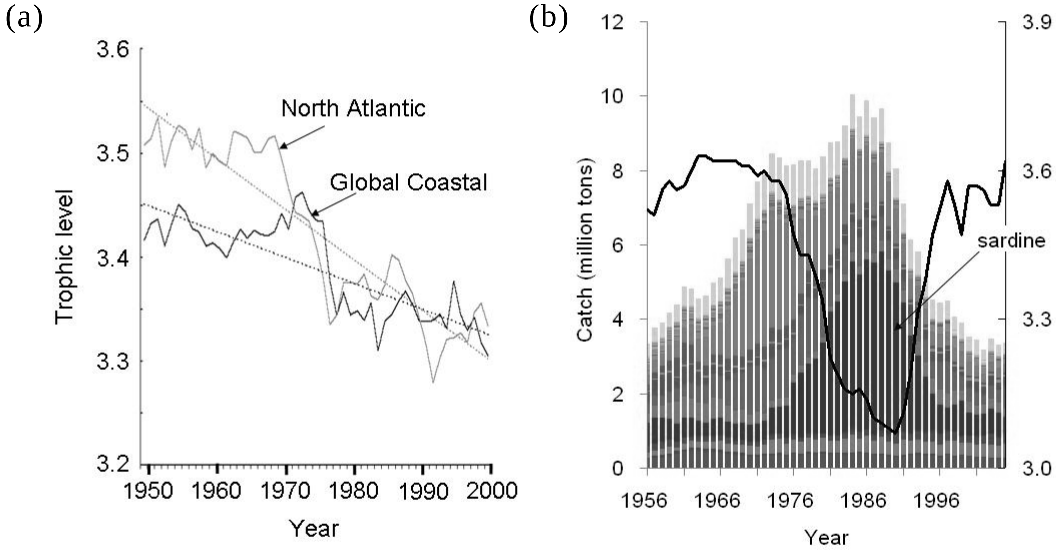

Figure 2.1 The mean trophic level (MTL) of fisheries landings, (a) MTL in the north Atlantic and global coastal oceans (Pauly and Watson 2005) and (b) MTL (bold line) and the total landings (bars) of the Japanese fisheries (Matsuda and Ijima, unpublished).

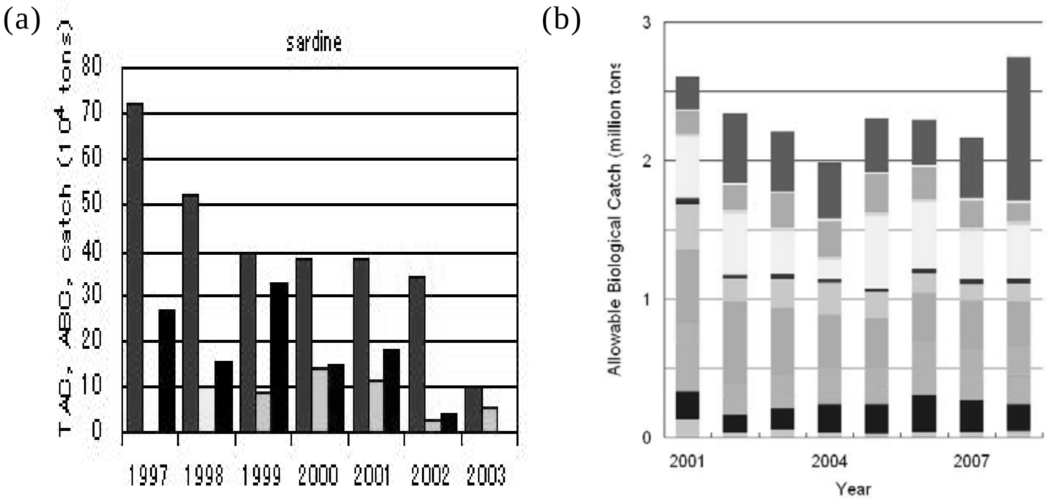

Figure 2.2 Status of total allowable catch in Japanese fisheries, (a) the allowable biological catch (ABC), total allowable catch (TAC) and actual catch of Japanese sardine during 1997–2003, (b) the sum of ABCs for several major species: Pacific saury, red sea bream, Arabesque greenling, cod, anchovy, round herring, snow crab, walleye pollock, common squid, spotted mackerel, chub mackerel, jack mackerel and sardine from top to bottom of each bar (Fisheries Research Agency, Japan, unpublished).

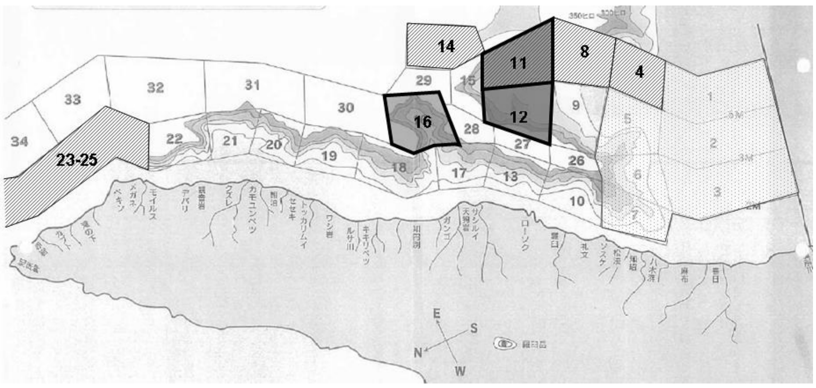

Figure 3.1 Protected areas (map is provided by Rausu FCA). Grids 11, 12 and 16 are spawning grounds. Grids 4, 8, 11, 14 and 23–25 are seasonal fishing ban areas since 1995. Grids 1–3 and 5–7 are seasonal fishing ban areas since 2005.

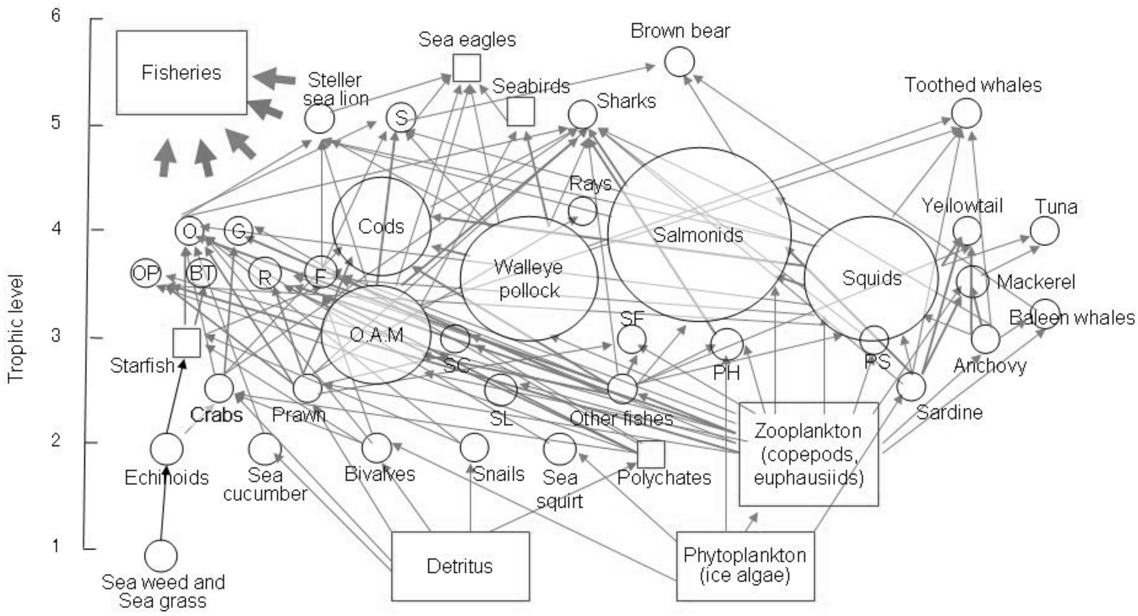

Figure 3.2 Flow diagram for the Marine Management Plan of the Shiretoko World Heritage site (minor revision from Makino and Matsuda 2008). Abbreviations mean: AG: Arabesque greenling, G: Greenling, O: Octopus, OP: Ocean perch, BT: Bighand thornyhead, R: Rockfish, F: Flatfish, S: Seal, PS: Pacific saury, SL: Sand lance, SC: Saffron cod, SF: Sandfish and PH: Pacific herring. Circles and squares mean utilised and unutilised organisms, respectively.

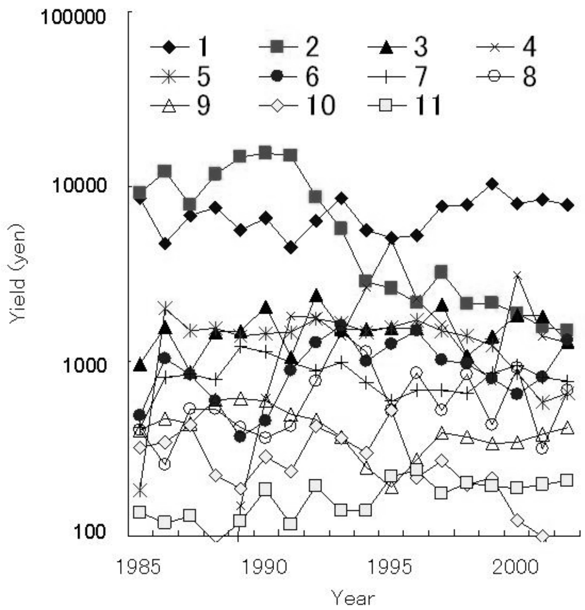

Figure 3.3 Fisheries yield for eleven major exploited taxa in the Shiretoko-daiichi, Utoro, and Rausu Fisheries Cooperative Associations (Ministry of the Environment, the Government of Japan, and Hokkaido Prefectural Government, 2007). Species names are: 1: chum salmon, 2: walleye pollock, 3: kelp, 4: common squid, 5: bighand thornyhead, 6:

Pacific cod, 7: Arabesque greenling, 8: pink salmon, 9: sea urchin, 10: scallop and 11: *Octopus dolfleini*.