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An ecosystem-based approach for Alaska groundfish fisheries

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An ecosystem-based approach is being developed for the management of groundfish fisheries in the North Pacific Ocean off Alaska, USA. The approach involves public participation, reliance on scientific research and advice, conservative catch quotas, comprehensive monitoring and enforcement, by-catch controls, gear restrictions, temporal and spatial distribution of fisheries, habitat conservation areas, and other biological and socioeconomic considerations. The basic ecosystem consideration employed is a precautionary approach to extraction of fish resources. Off Alaska, all groundfish stocks are considered healthy, while providing sustained yields of about 2 million tonnes annually. Management measures are also taken to minimize potential impacts of fishing on seafloor habitat and other ecosystem components such as marine mammals and seabirds.

Key words: Alaska, ecosystem, groundfish, management.

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Introduction

Ecosystem-based management strategies have been widely adopted throughout the United States for terrestrial and freshwater aquatic systems, but are just beginning to be applied to marine ecosystems (National Research Council, 1999). Fisheries may affect ecosystems in numerous ways. Populations of fish and other ecosystem components can be affected by the selectivity, magnitude, timing, location, and methods of fish removals. Fisheries can also affect ecosystems by vessel disturbance, nutrient cycling, introduction of exotic species, pollution, unobserved mortality, and habitat alteration. An ecosystem-based management strategy for marine fisheries would be to minimize potential impacts while allowing for extraction of fish resources at levels sustainable for both the fish stock and the ecosystem. Management measures consistent with an ecosystem-based strategy include conservative and precautionary catch limits, comprehensive monitoring and enforcement, by-catch controls, gear restrictions, temporal and spatial distribution of fisheries, marine protected areas, and other considerations.

The North Pacific Fishery Management Council has been developing an ecosystem-based approach for management of North Pacific groundfish fisheries. The Council is a regional organization established by the Magnuson–Stevens Fishery Conservation and Management Act in 1976 when the United States extended its fisheries jurisdiction out to 371 km. The Council, together with the National Marine Fisheries Service, has primary responsibility for groundfish management in the Gulf of Alaska, Bering Sea, and Aleutian Islands area, encompassing about 2.7 million km^2. Conservative management policies, such as catch limits and marine protection areas, were implemented with adoption of the first fishery management plans. Conservative policies were a result of limited information on stock abundance and the Magnuson–Stevens Act objective to "Americanize" the fisheries. The goals of the current fishery management plans include conserving fishery resources for optimum yield, maintaining productive fish habitats, and minimizing interactions with other elements of the ecosystem.

Management policies developed for Alaska groundfish fisheries are consistent with a precautionary approach and ecosystem-based management, and have resulted in sustainable fisheries. All groundfish stocks are considered relatively healthy after 20 years of sustained annual harvests of about 2 million tonnes and no fish stocks have been deemed overfished in a recent evaluation (NMFS, 1998a). When revised overfishing definitions were implemented in 1999, only one fishery resource in the region (Bering Sea Tanner crab,

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Chinoecetes bairdi) was determined to be below its minimum stock size threshold, and an aggressive rebuilding plan is being developed for this stock.

Although fish stocks remain healthy, concerns about the impacts of fish removals on other components of the ecosystem have motivated the Council to continue development of a more ecosystem-based management strategy. We review the Council's approach to date, and explore further progress towards integrating ecosystem considerations into management of groundfish fisheries.

Precautionary and conservative catch limits

Total removals of groundfish are controlled by annual catch limits established for each stock. For each target stock, three harvest levels are set, corresponding to the overfishing level (OFL), the acceptable biological catch (ABC), and total allowable catch (TAC). TACs are essentially annual catch limits for the fishery, and are established at or below the ABC. ABCs define acceptable harvests from a biological perspective, and OFL defines the unacceptable harvest. Specification of harvest limits is done to a precautionary manner (Thompson, 1996).

Harvest rate specifications are more conservative when less information is available. The maximum allowable rates are prescribed in descending order of preference, corresponding to descending order of information availability. Additionally, maximum sustainable yield (MSY) is treated as a limit, rather than as a target. For most stocks, ABC is based on a rate less than or equal to $F_{40\%}$, which is the fishing mortality rate associated with an equilibrium level of spawning per recruit equal to 40% of the equilibrium level in the absence of any fishing. If less information is available about the stock, ABC is generally based on three-fourths of the natural mortality rate (M). Both the $F_{40\%}$ and 0.75 M rates are considered conservative harvest rates for most groundfish stocks (Clark, 1993; Rosenberg and Restrepo, 1996). To further minimize the possibility of catches jeopardizing a stock's long-term productivity, there is a buffer established between ABC and OFL. For most stocks, OFL is defined based on a $F_{35\%}$ rate.

Harvest rates used to establish ABCs are reduced at lower than average stock size levels, thereby allowing rebuilding of these stocks. If the biomass of any stock falls below B_{msy} or $B_{40\%}$ (the long-term average biomass that would be expected under average recruitment and $F = F_{40\%}$), most fishing mortality rate is adjusted relative to stock status. This serves as an implicit rebuilding plan should a stock fall below a critical abundance.

As a result of these definitions, specified harvest rates for groundfish stocks are very low. Actual harvest rates are significantly lower for many species, as the TAC may be set much lower than ABC, and harvests may be less than TAC due to regulatory closures. All fish caught in any fishery (including by-catch), whether landed or discarded, are counted towards the TAC for that stock. Based on comprehensive onboard observer data and reports provided by the fleet, directed fisheries for each species or complex are closed before the TAC is reached. Observer data provide for accurate and precise estimation of Alaska groundfish catch (Volstad *et al.*, 1997). Because 100% mortality for all discards is assumed (yet some fish are likely to survive), actual removals may be lower than catch numbers indicate.

Additional precaution is incorporated in the catch specification for Bering Sea/Aleutian Islands groundfish. Since 1981, the annual TAC of groundfish for this region must fall within an optimum yield range of 1.4 to 2 million tonnes. This has limited the sum of TACs for all species to two million per year, which has been considerably less than the sum of all ABCs. In some years, ABCs have totalled more than 2.8 million tonnes. As a result, many stocks, particularly flatfish, have been exploited well below sustainable levels (Witherell, 1995).

Limits on by-catch and discards

The issues of by-catch, discard, and waste of fish resources stems from social, economic, and conservation concerns. From an ecosystem perspecitve, mortality of unwanted and "prohibited species" may reduce spawning potential, reduce biodiversity, alter regular paths of energy flow and balance, enhance the growth of scavenger populations, and add uncertainty to estimates of total removals. Fish are discarded for two reasons: either they must be thrown back due to regulations, or they are unwanted by that fishing vessel. In the North Pacific, discards of unwanted groundfish ("economic discards") result when fishermen do not have markets, sufficient equipment, time, or economic return to retain and process the catch (Queirolo *et al.*, 1995). In the 1997 Bering Sea/Aleutian Islands fisheries, a total of 258 000 t of groundfish was discarded, equating to about 15% of the total groundfish catch. Although this discard rate is lower than most of the world's groundfish fisheries, which average about 20% discards (Alverson *et al.*, 1994), the sheer volume is troublesome to many people who consider economic discards as waste of food and as having an impact on the ecosystem.

By-catch management measures have been established primarily for allocative reasons, rather than to address ecosystem concerns. Regulations have focused on reducing the incidental capture and injury of species traditionally harvested by other fisheries. These species include king crab (*Paralithodes* and *Lithodes* spp.), Tanner crab (*Chionoecetes* spp.), Pacific herring (*Clupea harengus pallasi*), Pacific halibut (*Hippoglossus stenolepis*), and

Pacific salmon and steelhead trout (*Oncorhynchus* spp.). Collectively, these species are called "prohibited species", as they cannot be retained as by-catch and must be discarded with a minimum of injury.

By-catch controls were instituted on foreign groundfish fisheries prior to passage of the Magnuson–Stevens Act in 1976 and have become more restrictive in recent years (Witherell and Pautzke, 1998). By-catch is monitored through a comprehensive and mandatory observer programme, which requires 100% observer coverage on vessels over 49 m; observer requirements for smaller vessels are less restrictive (Queirolo *et al.*, 1995). When a by-catch limit is attained based on fleetwide extrapolation of observer data, all vessels are prohibited from participating in the fishery for the remainder of the season. By-catch limits for 1998 Bering Sea and Aleutian Island groundfish trawl fisheries included 3775 t of halibut mortality, 1697 t of herring, 100 000 red king crabs, 2 850 000 *C. bairdi* crabs, 4 654 000 *C. opilio* crabs, 48 000 chinook salmon, *O. tshawytscha*, and 42 000 other salmon. These limits equated to about 0.1% of the red king crab and *C. opilio* crab populations, 1.8% of the *C. bairdi* crab population, 1% of the herring biomass, and 1.3% of the halibut biomass. The impact of salmon by-catch on Alaska populations remains unknown, but is thought to be <1% of the chum salmon population, and in the order of 2–4% of the adult chinook salmon population (NPFMC, 1999). To reduce the impact on the chinook population and on the salmon fishers, by-catch limits will be incrementally reduced to 29 000 salmon by the year 2003.

Gear restrictions and other regulatory measures have also been implemented to reduce by-catch and waste. Biodegradable panels are required for pot gear to minimize waste associated with ghost fishing of lost gear. Tunnel openings for pot gear are limited in size to reduce incidental catch of halibut and crabs. Gillnets for groundfish have been prohibited to prevent ghost fishing and to reduce by-catch of non-target species. Bottom trawling for Bering Sea pollock (*Theragra chalcogramma*) was recently prohibited to reduce by-catch and benthic disturbance.

To reduce discards, the Council adopted an improved retention and utilization programme for all groundfish target fisheries. Beginning in 1998, 100% retention of pollock and Pacific cod (*Gadus macrocephalus*) was required, regardless of how or where it was caught. Only fish not fit for human consumption can be legally discarded. This measure has reduced overall discard of groundfish. In 1997, about 22 100 t (8.6% of the catch) of cod and 94 800 t (8.2% of the catch) of pollock were discarded. In 1998, discards amounted to only 4300 t (2.2%) of cod and 16 200 t (1.6%) of pollock. A regulation requiring full retention of all demersal shelf rockfish species – e.g., yelloweye rockfish (*Sebastes ruberrimus*) – was adopted in 1999. Rock sole (*Lepidopsetta bilineata*) and yellowfin sole, *Limarda aspera*, retention will be required beginning in 2003; the delay will allow for development of new markets and gear technological responses by the vessels engaged in these fisheries. These retention requirements are expected to reduce overall discard rates from about 15% to about 5% by 2004.

Fishermen have altered their behaviour and reduced by-catch in response to fishery regulations. Both the long-line and trawl vessels voluntarily share information to identify and avoid areas with high halibut and crab by-catch rates. The individual fishing quota system for halibut and sablefish long-line fisheries has stopped the race for fish, and consequently has allowed for more selective fishing practices (Adams, 1995). Larger mesh sizes and other gear modifications are being made in trawl fisheries to reduce capture of small pollock and cod.

Marine protected areas

Several marine protected areas have been established to protect habitat for fish, crabs, and marine mammals (Fig. 1). Adequate habitat is essential for maintaining productivity of fishery resources, and some species or life stages require particular habitats for food, reproduction, and shelter from predators. In the Bering Sea, three large areas have been closed to groundfish trawling and scallop dredging to reduce potential adverse impacts on king crabs and crab habitat. In particular, the shallow areas contain complex living and non-living substrates, which are essential for juvenile crab survival and are considered to be very sensitive to bottom trawling. In the Gulf of Alaska, several discrete trawl closure areas have been established around Kodiak Island to reduce crab by-catch, but also serve to protect crab habitat. A very large no trawling area was established off Southeast Alaska, an area containing extensive coral distribution and other high-relief habitat. Bottom fishing with all gear types has been prohibited on a nearshore pinnacle that was identified as a rare, vulnerable, and ecologically important area. Closure of Cook Inlet to bottom trawling has been proposed to protect the area's crab habitat.

These marine protected areas comprise a relatively large portion of the continental shelf, and in many respects serve as marine reserves. In total, the three Bering Sea area closures encompass about 89 500 km^2, more than twice the area of Georges Bank off the east coast of the United States. The Gulf of Alaska closures encompass about 140 200 km^2, but a vast majority (80–90%) of this area is off the continental shelf (>200 m). Lauck *et al.* (1998) recently suggested that marine reserves should be at least 20% of available habitat in order to be effective. The Bering Sea marine protected areas exceed this threshold by encompassing about 25% of the shelf where commercial quantities of groundfish

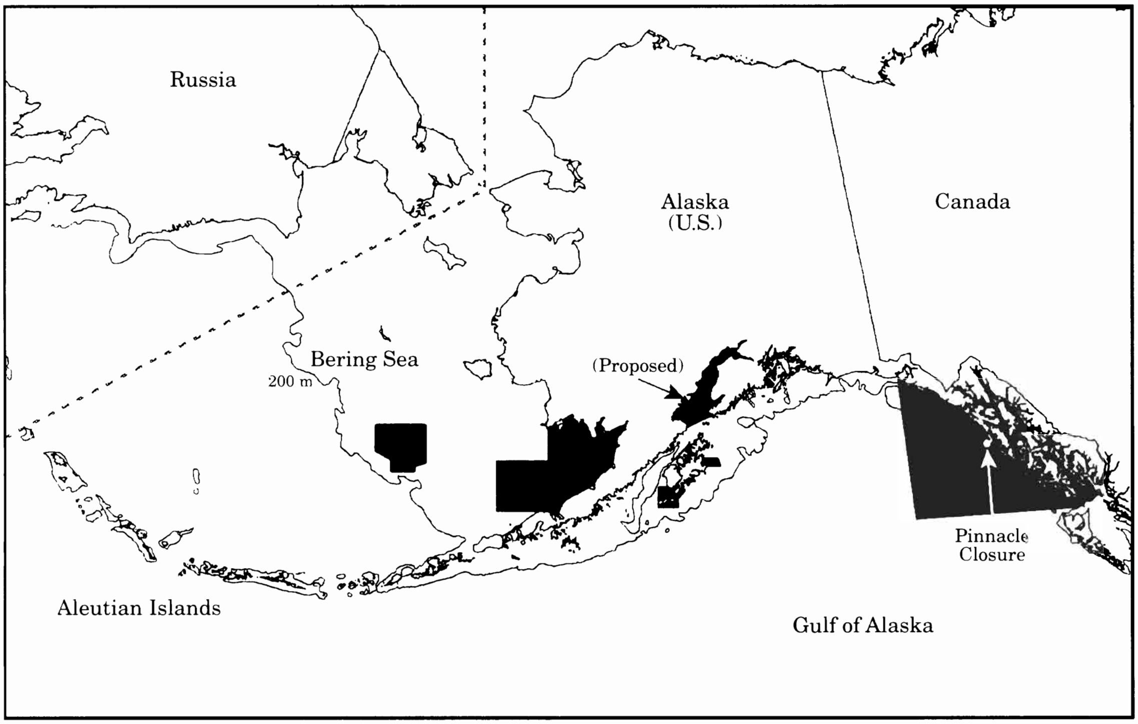

Figure 1. Location of marine protected areas off Alaska where trawling is prohibited year-round to protect fish and crab habitat and reduce by-catch.

can be taken with bottom-trawl gear, based on interpolation of fishery location data from Fritz *et al.* (1997). Existing Gulf of Alaska area closures encompass less than 10% of the trawlable shelf area.

The 1996 Magnuson–Stevens Act amendments required that all fishery management plans include a description and identification of essential fish habitat, adverse impacts, and actions to conserve and enhance habitat. In 1998, the Council defined essential fish habitat based on general fish distribution. Maps of these areas will be useful for understanding potential threats from proposed development and other activities. The next step is to identify habitat areas of particular concern based on ecological function and vulnerability to anthropogenic impacts. An example would include areas with slow-growing corals that are extremely sensitive to impacts. Once these areas have been identified, potential threats due to fishing activities can be evaluated and additional measures implemented as needed. Because the Council has found marine protected areas to be a useful tool in managing by-catch and habitat protection, it is likely that additional areas will be established.

Marine mammal and seabird considerations

Measures have been implemented to reduce potential impacts of localized depletion of prey for higher trophic levels. Because pollock is a primary prey item for endangered Steller sea lions (*Eumetopias jubatus*), pollock fisheries could potentially jeopardize the continuing existence of the sea lions and imperil their recovery (NMFS, 1998b). To address these concerns, several precautionary management measures have been implemented. The TACs for pollock and Atka mackerel (*Pleurogrammus monopterygius*), both important prey for sea lions, were spatially and seasonally apportioned into smaller sub-TACs to prevent prey removals from occurring all at once, and in localized areas. In the Aleutian Islands region, all pollock fishing has been prohibited to eliinate any potential competition with sea lions.

Area closures have also been implemented to prevent disrupting marine mammals at rookeries and haulouts, and to reduce competition from fisheries. To protect Pacific walrus (*Odobenus rosmarus*), fishing vessels are prohibited in that part of the Bering Sea within 22 km of Round Island, the Twins and Cape Pierce in northern Bristol Bay during summer. To protect Steller sea lions, no trawling is allowed year round within 18.5 km of numerous rookeries, and trawling for pollock is prohibited near haulouts (Fig. 2). A number of these no-trawl zones extend out to 37 km on a seasonal basis.

In 1997, the Council adopted a regulation that prohibits directed fishing for forage fish species such as capelin (*Mallotus villosus*) and a host of other

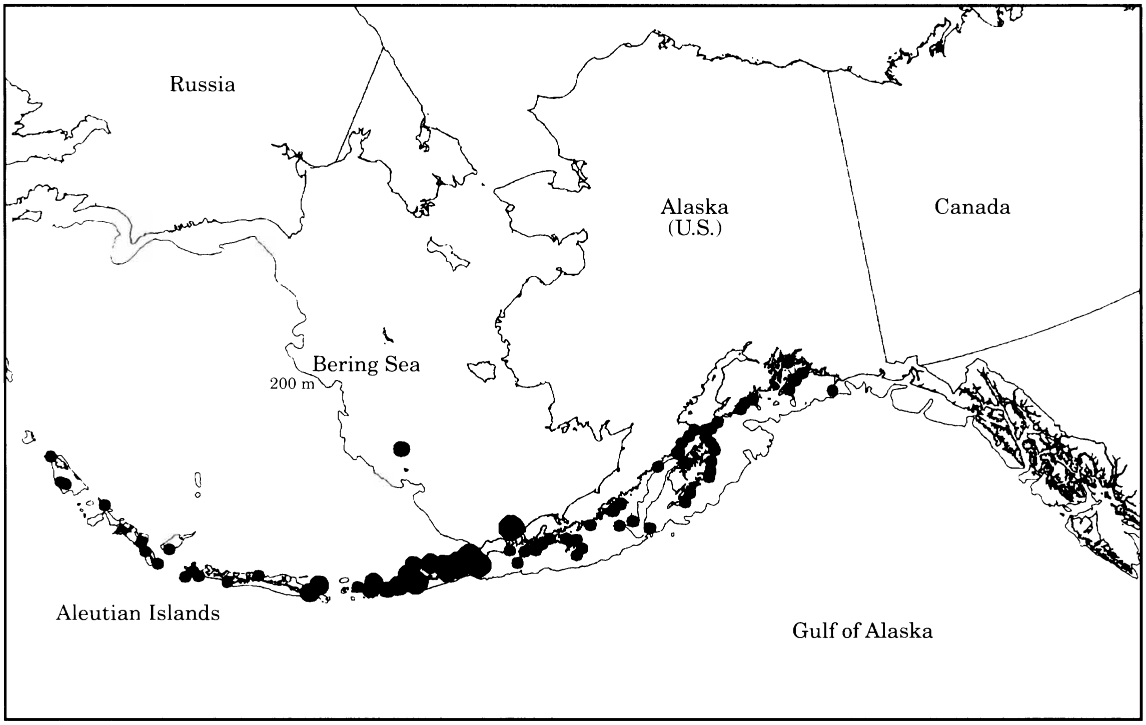

Figure 2. Location of the zones around Steller sea lion rookeries and haulouts where trawling is restricted to reduce competition for prey.

forage species, including euphausiids (krill), which are important prey for higher trophic levels. Limited commercial fisheries for Pacific herring have traditionally been prosecuted in State waters, so herring was the only forage fish species exempted from the regulation.

Regulations have also been established to reduce direct mortality of mammals and seabirds. Incidental catch limits have been established for Steller sea lions and the endangered short-tailed albatross (*Diomedea albatrus*) based on criteria that incidental mortality should have negligible impacts on the affected species or stock. Concern for the incidental by-catch of seabirds led to regulations requiring that deterrent devices be employed on groundfish long-line vessels beginning in 1997. Approximately 9600 seabirds (including 1 albatross) are incidentally killed in Alaska groundfish fisheries each year (K. Wohl, USFWS, unpublished data). It is hoped that these deterrent devices, which are actively being developed and improved upon by fishermen, will significantly reduce incidental mortality.

Continued progress towards ecosystem-based management

The development of a more ecosystem-based management strategy has progressed at all levels, from science to policy making. Since 1995, the groundfish plan teams have prepared an Ecosystem Considerations section to supplement the annual Stock Assessment and Fishery Evaluation report (e.g., NPFMC, 1998). This chapter provides an annual assessment of the ecosystem, a review of recent ecosystem-based management literature, updates of ongoing ecosystem research, local observations from coastal people and fishermen, and new information on the status of seabirds, marine mamals, habitat, and other components of the North Pacific ecosystem. These chapters will include in the future more data analysis, such as standardized ecosystem status and trend indicators, which can serve as reference points for the overall management strategy.

In 1996, the Council established an ecosystem committee to discuss possible approaches to incorporating ecosystem concerns into the fishery management process. The committee has held workshops, meetings, and numerous informal discussions on related issues and habitat concerns. The committee provides the Council and stakeholders with information, and provides feedback to scientists on research needs. The committee also developed a draft policy for ecosystem-based management of North Pacific fisheries (Table 1) based on principles and elements identified in the scientific literature (e.g., Grumbine, 1994; Mangel *et al.*, 1995; Christensen *et al.*, 1996).

Table 1. The Council's draft ecosystem-based management policy.

Definition	Ecosystem-based management is a strategy to regulate human activity towards maintaining long-term system sustainability (within the range of natural variability as we understand it) of the North Pacific.
Objective	To provide future generations the opportunities and resources we enjoy today.
Goals	
	1. Maintain biodiversity consistent with natural evolutionary and ecological processes, including dynamic change and variability.
	2. Maintain and restore habitats essential for fish and their prey.
	3. Maintain system sustainability and sustainable yields of resources for human consumption and non-extractive uses.
	4. Maintain the concept that humans are components of the ecosystem.
Guidelines	
	1. Integrate ecosystem-based management through interactive partnerships and other agencies, stakeholders, and public.
	2. Utilize sound ecological models as an aid in understanding the structure, function, and dynamics of the ecosystem.
	3. Utilize research and monitoring to test ecosystem approaches.
	4. Use precaution when faced with uncertainties to minimize risk; management decisions should err on the side of resource conservation.
Understanding	
	1. Uncontrolled human population growth and consequent demand for resources are inconsistent with resource sustainability.
	2. Ecosystem-based management requires time scales that transcend human lifetimes.
	3. Ecosystems are open, interconnected, complex, and dynamic.

Discussion

Ecosystem considerations are being incorporated into management of Alaska groundfish fisheries. Steps are being taken to lessen human impacts on the environment due to fishing, while at the same time providing sustained yields of fishery resources. Unlike many groundfish stocks in other areas of the world, catches of groundfish have been sustained, and many restrictions implemented to reduce impacts on other ecosystem components.

The basic ecosystem consideration is a precautionary approach to extraction of fish resources. The precautionary principle was developed over the past 10 years as a policy measure to address sustainability of natural resources in the face of uncertainty. Because precise impacts caused by human activity cannot be known with certainty, a conservative approach is required (Dovers and Handmer, 1995), particularly when there is a high level of uncertainty and there are large (potentially irreversible) costs if a mistake is made (Garcia, 1996). Fisheries management around the world has traditionally been based on a preventive and trial-and-error approach, yet the collapse of some fisheries indicates that a more precautionary approach should have been applied. New national legislation and international fishery agreements are pushing fishery management towards a new paradigm whereby MSY is treated as a limit to be avoided rather than as a target that can be exceeded. Mace (1999) refers to this system as one of conscious under-exploitation of natural marine resources so that marine ecosystems are preserved in perpetuity while still contributing to food production, recreation, and other human uses. If fisheries are managed sustainably using a precautionary approach, it is likely that the overall ecosystem processes, ecosystem integrity, and biodiversity are also protected to some degree.

Although measures implemented to date seem to be successful at achieving specified objectives, ecosystem-based management is an adaptive process and will require periodic evaluation and modification to incorporate new scientific information as it becomes available. Additionally, ecosystems are not static, and human impacts also change with technology and continued population growth. Ocean conditions can cause significant, rapid, and sometimes unexpected changes in ecosystem components. Because still little is known about marine ecosystems, an adaptive and precautionary approach is essential for all fishery management policies.

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