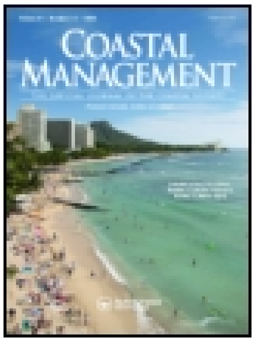

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Potential Benefits of Coastal Ocean Observing Systems to Alaskan Commercial Fisheries

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In this article we attempt to illustrate the potential benefits to Alaskan commercial fisheries expected from enhancements to the Alaska Ocean Observing System (AOOS) through changes in fishery management strategies. In particular we show how the use of improved AOOS data in research, stock assessment, and ultimately fisheries management has the potential to result in significant benefits in the Bering Sea and Gulf of Alaska groundfish and Kodiak king crab fisheries. We show through a case study approach that information such as might be provided by an enhanced AOOS could conceivably contribute over \$600 million in additional annual revenue in Alaska's groundfish fishery. In addition we estimate that had the information from such a system been available in the 1970s and 1980s the Kodiak king crab stock collapse could have been avoided and \$60 million in annual revenues generated. Benefit estimates (as measured by revenue increases) are based on the assumptions that when better data is delivered those data will be integrated into stock assessment models; when better data are integrated into the models the new data will actually improve the reliability of the models; and when the reliability of the models is improved predictions will be accepted by managers or industry members.

Keywords Alaska fisheries, coastal observing systems, economic benefits, value of information

Introduction

This article describes an assessment of the potential value of information from an enhanced Alaska Ocean Observation System (AOOS) to select Alaskan commercial fisheries. The value of information is measured as a change in revenue resulting from increased harvest rates and avoidance of overfishing as dictated by fishery management strategies. Because the current and potential use of AOOS data in research, stock assessment and ultimately fisheries management varies considerably from fishery to fishery we chose a case study approach to the assess the value of improved coastal ocean observing systems to the commercial fisheries of the Alaska region. The case studies include: (1) Bering Sea and Gulf of Alaska groundfish; and (2) Kodiak king crab fisheries. These case studies offer a qualitative discussion of the current and optimal coastal ocean observation systems information scenarios, decision-making and physical outcomes and a quantitative analysis of economic outcomes based

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on plausible scenarios. All assumptions and limitations to the economic assessment of the value of an improved AOOS are stated explicitly in the third section.

The analysis and final conclusions of this report were generated using information provided through interviews with Directors of the Alaska Ocean Observing System (AOOS) and Northwest Association of Networked Ocean Observing Systems (NANOOS) and over 25 biologists, oceanographers, fisheries managers, and fishers. We also relied on scientific studies, North Pacific Fisheries Management Council Stock Assessment Fishery Evaluation reports, and relevant secondary literature.

Background

Alaska Ocean Observation System

The Alaska Ocean Observing System (AOOS) is part of a growing national network of integrated ocean observing systems that has the potential to improve the ability to rapidly detect changes in marine ecosystems and living resources, and predict future changes and their consequences for the public good (http://www.aoos.org). While AOOS is just in its developmental stage the system covers three zones, including (1) the Gulf of Alaska/Southeastern Alaska; (2) the Aleutian Islands/Bering Sea; (3) the Artic Ocean/Beaufort Sea/Chukchi Sea. Currently data collected in these zones by various institutions and programs include atmospheric measurements (Doppler radars, wind profilers, meteorological stations, FAA Weathercams, and Satellite), oceanic measurement (NOAA buoys, UAF buoys, CODAR, tide gauges, NOS/NDBC water temps, and satellite), and river, soil and snow measurements (USDA SNOTEL Met Stations, Toolik Lake Research Station, USGS Streamflow data, USDA SCAN Met Stations, NWS/USGS River Stage and Flow Data, and NWS/USGS Snow Data Sites). Related programs include DOE/Atmospheric Radiation Measurement Program PWSSC Nowcast/Forecast Project, GEM Project, SALMON Project, GLOBTEC, and the Alaska Sea Life Center Research. The types of measurement and level of coverage varies across the three Alaskan zones (http://www.ims.uaf.edu:8000/caos/zone_1.html; zone_2.html; zone_3.html).

AOOS represents a partnership that has been formed to develop a regional program in Alaska. Partners include the State of Alaska; federal agencies such as the National Oceanic and Atmospheric Administration and the Department of Interior; Academic institutions including the University of Alaska and University of Washington; research organizations such as the North Pacific Research Board, the Alaska SeaLife Center, the Prince William Sound Science Center, and the Barrow Artic Science Consortium; and industry groups including fisheries and aquaculture associations. AOOS' goal is to provide a centralized location for (1) new buoy data—wind and current speed and direction, wave height, sea temperature, and salinity, (2) enhancements to existing NOAA weather buoy data for specialized local needs; (3) processed satellite data providing Alaska-wide information on sea-surface temperature, ocean color (chlorophyll) and wind; (4) geographically comprehensive surface current data from high frequency radar; and (5) data about fish, birds and marine mammals, the environmental effects of human activities, and any other information that can be used with the physical data to predict future changes to ocean ecosystems.

Overview of Selected Commercial Fisheries in Alaska

Groundfish. The Alaska groundfish fisheries are dominated by harvests of walleye pollock, which since 1998 have been between 60–75% of harvests by volume (Table 1). During that

Table 1
Alaska groundfish harvests by species group, 1998–2002

Year	Pollock	Black cod	Pacific cod	Flatfish	Rockfish	Atka mackerel	Total
			Alaska total—millions of pounds				
1998	2756.2	36.2	568.6	491.8	76.9	126.5	4056.2
1999	2395.1	33.7	534.6	534.6	97.9	124.6	3720.5
2000	2668.2	38.6	541.4	541.4	83.6	104.5	3977.8
2001	3220.7	33.3	481.5	379.2	86.2	135.8	4336.7
2002	3387.0	31.9	515.8	391.2	94.1	105.3	4525.3

Source: Economic Status of the Groundfish Fisheries off Alaska, 2002, by Terry Hiatt et al., 2003.

same period harvests of Pacific cod and flatfish have averaged roughly 12% while harvests of other species are much smaller by volume. Ex-vessel and processed product values of Alaska groundfish from 1998–2002 are shown in Table 2. Ex-vessel value of harvests (the estimates value of raw fish harvested)[1] increased significantly from 1998–2000 primarily because of the rationalization of the Pollock fishery under the 1998 American Fisheries Act (AFA). AFA allowed vessels to form cooperatives and effectively ended the "race for fish" in the Pollock fishery. A similar increase in the wholesale values is seen over the same period. The additional value of the Pollock fishery can be attributed to efficiency gains achieved through the reduction of active vessels in the Pollock fishery and the coordination of effort through the cooperative system.

Table 2
Value of Alaska groundfish by species group, 1998—2002

Year	Pollock	Black Cod	Pacific Cod	Flatfish	Rockfish	Atka mackerel	Total
			Ex-Vessel Value of Harvest ($ Millions)[1]				
1998	179.6	52.9	98.8	36.2	8.0	7.9	383.6
1999	211.2	57.0	141.9	30.2	11.0	9.8	461.4
2000	298.0	75.8	157.7	41.1	9.8	9.5	592.5
2001	295.2	61.9	124.8	31.5	7.9	21.1	542.6
2002	321.6	64.4	121.7	37.2	9.7	11.2	566.2
			First Wholesale Value of Processed Products ($ Millions)[2]				
1998	492.3	68.3	213.6	83.4	18.7	17.5	1024.8
1999	690.2	73.0	273.6	70.7	20.7	21.9	1178.1
2000	814.3	87.1	285.9	91.9	19.0	21.2	1345.8
2001	929.8	79.5	235.4	61.5	15.6	44.6	1390.8
2002	987.0	81.5	245.2	86.1	22.5	24.9	1482.8

Source: Economic Status of the Groundfish Fisheries off Alaska, 2002, by Terry Hiatt, et al.
[1]Estimates of ex-vessel value include an implicit value for fish harvested by catcher processors.
[2]Estimates of wholesale value are based on values reported by processors as product leaves the plant.
Note: Values shown are not adjusted for inflation.

Table 3
Value, payments to labor and employment in Alaska groundfish fisheries by sector, 2001

Sector	Value ($ Millions)	Payments to labor ($ Millions)	Employment (FTE)
Catcher processors	743.9	265.9	3876.7
Motherships and shore-based processors	682.9	266.9	4490.5
Catcher vessels	288.5	115.4	2015.7
All sectors	1426.9	648.2	10383.0

Source: Alaska Groundfish Final Programmatic SEIS. NMFS, 2004.
Note: the total value of all sectors does not add the value earned by catcher vessels—those values are a cost to motherships and shore-based processors and are included in the total wholesale value.

It should be noted that reporting only the value of raw fish (ex-vessel value) significantly understates the value of the fisheries, particularly in the case of the fisheries that include catcher processors (CPs). CPs, which catch and process fish, account for approximately 54% of the wholesale value of Alaska groundfish harvests. In addition, motherships, large processing ships that take deliveries of raw fish at sea, account for approximately 6% of the wholesale value. The remaining 40% of wholesale value is generated by traditional shore-based processing plants. As seen in Table 3 Alaska groundfish fisheries generated over $600 million in direct income for fishing crews and processing labor, and boat and facility owners, and employed over 10000 persons in 2001.

Table 4 shows estimates of the total biomass, spawning biomass, the Allowable Biological Catch (ABC) and actual total catch and exploitation rates of Alaska groundfish by major species groups in 2002. The estimates demonstrate the relatively conservative harvest policy employed in the North Pacific (Ianelli, 2003). Overall exploitation is less than 8.5% of total biomass, but more importantly harvests are 70% of ABCs.

Alaska Crab Fisheries. Table 5 illustrates ex-vessel values of Alaska crab harvests by species for 1993–2002. In the last 5 years reported the value of king crab harvests has surpassed the value of other species. Figure 1 illustrates crab harvests by species over a 30-year period. The figure shows that king crab harvests peaked in 1980 and then fell to approximately 25 percent of peak levels. The tanner crab fishery (also known as snow crab) peaked in 1991 and then fell dramatically, peaked again in 1998 and since 2000 has been harvested at levels less than 15% of record harvests. Figure 2 offers a longer historical perspective and demonstrates how different king crab fishery areas have experienced different peaks and declines. During the 1960s the Kodiak area was a major producer of king crab with a peak in 1965 and a precipitous decline by the end of the decade. The Kodiak fishery continued at low levels until 1982 when the fishery was closed. It has remained closed ever since. Following the collapse of the Kodiak fishery in the late 1960s, fishing effort migrated into Bristol Bay. The Bristol Bay fishery expanded rapidly during the 1970s and peaked in 1980, then collapsed similar to the Kodiak fishery. The Bristol Bay fishery has continued albeit at relatively low levels and with periodic closures.

Table 4
Biomass, allowable biological catch, and catch of Alaska groundfish, 2002

Species group	Total biomass (millions of lbs.)	Spawning biomass (millions of lbs.)	ABC (millions of lbs.)	Catch (millions of lbs.)	Exploitation (percent)
			Bering Sea and Aleutian Islands		
Pollock	28,586	8,114	3,843	3,276	11.46
Black cod	181	65	16	4	1.99
Pacific cod	4,260	892	644	403	9.47
Flatfish[1]	11,143	4,080	778	320	2.87
Rockfish[1]	826	303	62	46	5.58
Atka mackerel	1,057	261	144	105	9.92
BSAI Total	46,054	13,715	5,492	4,155	9.02
			Gulf of Alaska		
Pollock	1,502	300	388	111	7.40
Black cod	449	161	40	28	6.30
Pacific cod	1,253	216	164	112	8.97
Flatfish [1]	4,002	2,455	399	71	1.79
Rockfish [1]	1,105	401	70	48	4.34
Atka mackerel	NA	NA	1	0	NA
GOA Total	8,311	3,533	1,183	438	5.27
			Alaska Total		
Grand Total	54,365	17,247	6,675	4,594	8.45

Source: Ianelli, 2003. "North Pacific Multi-Species Management Model" in NMFS 2004.
[1]Biomass estimates of several species in this group are unavailable.

Fishery Management Decision-Making

Prediction of fish stocks or population levels plays a critical role in fisheries management decision-making. Prediction of stock size is critical to the underlying principals or goals of sustainable fisheries management. As such the role of fishery scientists is great in the overall decisions about harvest strategies. However, there continues to be tremendous uncertainty in stock size projections and thus continued potential for less than perfect decision making at the management level. Authors such as Solow et al. (1998) have been able to use data on enhanced forecasts of oceanographic conditions to formulate predictions of crop yields which are then used by farmers to optimize cropping patterns. The Bayesian decision theory approach that they use could potentially provide a methodology to aid fisheries managers in optimizing fish harvest (given the constraints of provisions of the MSFMCA and other pertinent legislation and regulation and fishery management objectives through the ten National Standards for Fishery Conservation and Management). The Bayesian approach could be used as a tool to make predictions and explore the consequences of alternative scenarios for a particular fishery within a particular ecosystem.

That said, it is instructive to qualitatively outline the decision model that is used in fisheries management decision-making in the Alaska region. Goodman et al. (2002, 1–2)

Table 5
Ex-vessel value of Alaska crab fisheries by species, 1993—2002

	Ex-vessel value ($ Millions)				
Year	King Crab	Dungeness Crab	Tanner Crab	Other crab	All crab species
1993	93.5	5.0	219.4	3.1	321.0
1994	59.9	5.5	241.7	5.8	312.9
1995	48.6	9.2	192.8	5.4	256.1
1996	67.8	6.0	94.4	1.9	170.1
1997	60.3	10.7	92.9	2.1	166.0
1998	60.6	4.3	139.7	0.8	205.5
1999	92.4	6.6	188.8	0.7	288.5
2000	62.2	4.5	56.7	0.0	123.5
2001	64.7	7.5	37.7	0.0	109.8
2002	81.3	8.6	42.0	0.0	132.0

Source: Basic Information Tables from Commercial Fishing Entry Commission Internet site at www.cfec.state.ak.us. Accessed June 2004.
Note: Values are shown in nominal dollars.

provides an excellent outline of the very complex process by which harvest strategies are chosen.

Alaska's groundfish fisheries are managed primarily by the Federal government (the National Marine Fisheries Service (NMFS) and the North Pacific Fishery Management Council (NPFMC or Council)).[2] Management of the groundfish fisheries are based on Fishery Management Plans (FMP) (one FMP for the Bering Sea and Aleutian Islands (BSAI) and one FMP for the Gulf of Alaska (GOA)) summarized in the Alaska Groundfish Fisheries Final Programmatic Supplemental Environmental Impact Statement (SEIS)

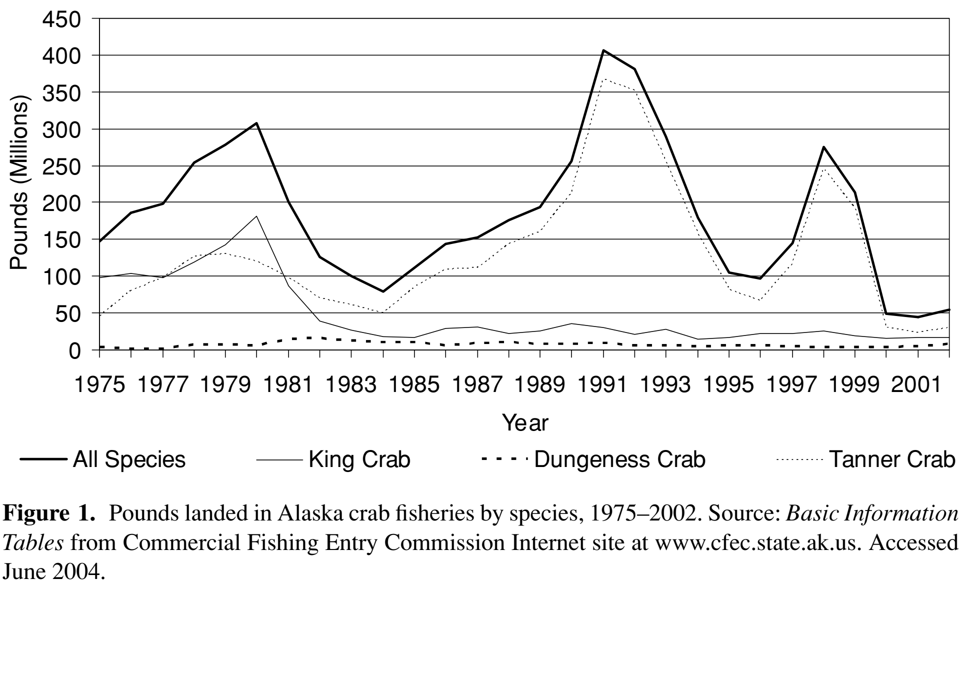

Figure 1. Pounds landed in Alaska crab fisheries by species, 1975–2002. Source: *Basic Information Tables* from Commercial Fishing Entry Commission Internet site at www.cfec.state.ak.us. Accessed June 2004.

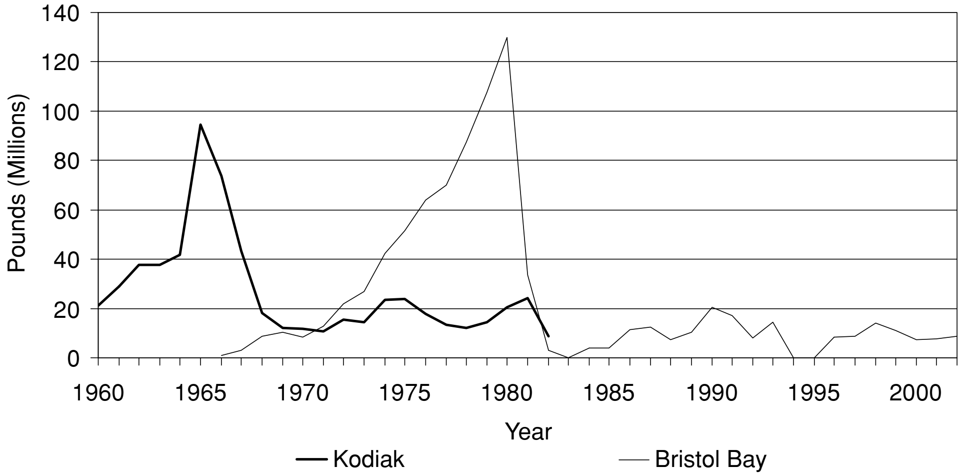

Figure 2. The rise and fall of major King Crab fisheries in Alaska, 1960–2002. Source: *Westward Region Shellfish Report*, 2002. ADF&G. Kodiak Alaska, 2003.

(NMFS, 2004). In general, the groundfish fisheries are quota-based fisheries. The annual harvest quotas, or Total Allowable Catch (TAC), are determined on a species by species basis within each FMP. Each summer and fall, fisheries scientists review new data and augment predictive models to assess stocks of each species and to determine how much can be harvested without putting the stocks at risk of falling below the Maximum Sustainable Stock Threshold (MSST). The level at which each species may be harvested is known as the Allowable Biological Catch (ABC). The scientist's recommendations for ABCs, which are generally quite risk averse are based on the "best available scientific data" and the amount of uncertainty, are forwarded to the NPFMC where they are reviewed by the senior scientists comprising the Council's Scientific and Statistical Committee (SSC). The Council's Advisory Panel (AP), comprised of representatives from the public and the seafood industry, takes the ABCs forwarded by the SSC and recommends TAC levels for each species. The AP's TAC recommendations take into consideration factors such as the level of demand for specific species and other business/political factors. In the GOA, the recommended TACs are often very similar to recommended ABCs. In the BSAI, however, a 2 million metric ton (MT) cap (4.4 billion pounds) limits the overall harvest of groundfish, even though the sum of ABCs of the various species in the BSAI far exceeds the cap.[3]

The current harvest decision-making strategy is essentially a maximum sustainable yield (MSY) single-species approach, modified by some formal safeguards incorporated to ward against overfishing as defined from the single-species stand point, and with opportunities of a less-structured nature for reducing harvest rates further in response to perceived social, economic and ecological concerns. No quantitative standards or specific decision rules are stated for these latter considerations, except as they are imposed, from outside the MSFCMA, by the Endangered Species Act or the Marine Mammal Protection Act.

The overfishing level (OFL) set for each stock is an estimate either of the fishing mortality rates associated with MSY (Fmsy) or an estimate of a surrogate for Fmsy. The OFL is treated in the management system as a limit that should not be exceeded except with a very low probability. The acceptable biological catch (ABC) set for each stock is an estimate of a target rate, which is intended to establish some margin between it and the OFL. The hope is that managing so as to achieve this target on average will accomplish the desired compliance with exceeding the limit (OFL) only rarely. The ad hoc downward adjustments of harvest in response to other social, economic, and ecological considerations takes place in the deliberations where the total allowable catch (TAC) is set subject to the constraint that it be less than or equal to the ABC.

The component of the reduction of harvest rate from the theoretical MSY harvest rate (from OFL to ABC) is an amount that is often modest, when expressed as a fraction of the harvest rate; but in terms of the total tonnage involved, or its dollar value, the amount is considerable. The margin is also small relative to real natural variation and small relative to the practical uncertainty about stock status or population parameters for many of the target stocks and indeed for most of the ecosystem. By contrast, in actual practice, the reduction in TAC from ABC has for some stocks and some years been quite large, but there is no explicit and general formula for this reduction. Many stock assessment scientists believe that this buffer should be better linked to uncertainty in both the measurement and process error (Hollowed, 2004).

The formal and standardized quantitative portions of the process for determining OFL and ABC begin with the assignment of each stock to one of six "Tiers" based on the availability of information about that stock. Tier 1 has the most information and Tier 6 the least. The so-called F40% construct plays a prominent role in some of the Tiers but not others. F40% is the calculated fishing mortality rate at which equilibrium spawning biomass per recruit is reduced to 40% of its value in the equivalent unfished stock. This is an esoteric, but useful, measure of the amount by which the associated fishing rate reduced the stock size, in the long run. The useful features of this particular measure are two-fold. First, its calculation is less sensitive to the details of the stock-recruitment relationship than is the calculation of Fmsy, so it is practical to estimate F40% for stocks that are not well enough studied for estimation of Fmsy. The second is that for a range of dynamics encompassing many, but not all, of the BSAI/GOA target groundfish stocks, for example, modeling studies have shown that harvesting at F35% accomplishes about the same thing as harvesting at Fmsy, so harvesting at the slightly lower rate, F40% established a modest margin of safety.

Currently, management of king and Tanner crab fisheries are under the jurisdiction of the Alaska Department of Fish and Wildlife and National Marine Fisheries Service in the Bering Sea and Aleutian Islands. Alaska Department of Fish and Game has sole jurisdiction of management of crab in the Gulf of Alaska. An annual scientific stock assessment and fishery evaluation (SAFE) report is required of them by the North Pacific Fisheries Management Council. The SAFE summarizes among other things, guideline harvest levels (GHL) and analytical information used for management decisions or changes in harvest strategies. According to the 2003 SAFE for King and Tanner Crab Fisheries in the Bearing Sea and Aleutian Islands, the Federal requirements for determining the status of the stocks are the minimum stock size threshold (MSST) and the maximum fishing mortality threshold (MFMT). These requirements are contained in the Fisheries Management Plan (FMP). The MSST is 50% of the total spawning biomass (SB or TMB = total mature biomass) for the period 1983–1997, upon which the maximum sustainable yield (MSY) was based. A stock is overfished if the SB is below the MSST. The MFMT is represented by the sustainable yield (SY) in a given year, which is the MSY rule applied to the current SB (the MSY control rule is $F = 0.2$ for king crabs and $F = 0.3$ for Tanner and snow crabs). Overfishing occurs if the harvest level exceeds the SY in one year. GHLs are developed from joint

NMFS and ADF&G assessment of stock conditions based on harvest strategies developed by ADF&G.

Regular trawl and hydroaccoustic survey results for five stocks (Pribilof blue king crab, St. Matthew blue king crab, Bristol Bay red king crab, eastern Bering Sea Tanner crab (*c. bairdi*), and eastern Bering Sea snow crab (*c. opilio*)) are compared to thresholds established by the State of Alaska harvest strategies and regulations. ADF&G uses these thresholds to determine if a fishery should be opened and to calculate GHL. For example, the Bering Sea Tanner crab fishery was closed in 1997 due to near record low stock abundance in the 1997 NMFS survey and poor performance in the 1996 fishery. ADF&G will reopen the fishery when the female biomass is above the threshold and the fishery GHL is above the minimum identified in the rebuilding harvest strategy or MSY biomass defined in the FMP as 189.6 million pounds of total mature biomass.

Assessment of the Potential Benefit of an Enhanced Ocean Observation Program

Assumptions

There are several factors, as explicitly outlined in what follows, that lead to uncertainty around the estimates generated in this work.

- It is unknown whether the proposed changes to the ocean observation program will actually deliver more and "better" data.
- Assuming better data is delivered, it is unknown whether or when those data will be integrated into stock assessment models.
- Assuming better data are integrated into the models it is unknown whether the new data will actually improve the reliability of the models and thus decrease uncertainty of actual stock levels.
- Assuming the reliability of the models is improved, it is unknown whether or when the improvements will be accepted by managers or industry members.

These types of uncertainties lead to conservative expected value of information estimates. To assess benefits to the Alaska groundfish fishery of enhanced data, a value of information model (using hypothetical probabilities) is expressed as follows:

- There is a 75% probability that groundfish scientists will be able to use the data to refine their analyses.
- There is a 50% probability that what scientists think today will be borne out by their further analyses and data.
- There is a 50% probability that the NPFMC and NOAA NMFS will lift the 2 million MT TAC cap, once a track record is established.
- There is a 50% probability that groundfish stocks will be in the same shape they are in 25 years from now.

An expected value model combines the above probabilities multiplicatively. Thus based on the hypothetical probabilities described herein, there is a 9% chance ($0.75 \times 0.5 \times 0.5 \times 0.5$) that the potential benefits estimated will be realized.

Model

As indicated in an earlier section, stock assessments and harvest quotas for Alaska groundfish take into account the amount of uncertainty in each of the utilized species. Scientists recommend relatively low ABCs for species with high levels of uncertainty in key variables, but will recommend relatively high ABCs for species where there is more certainty. The risk adverse nature of groundfish harvest strategies is furthered by an absolute cap on TACs in the Bering Sea of 2 million metric tons (4.4 billion pounds).

Currently NMFS is correct only 60% of the time in their annual pollock stock assessment. It is suggested, however (Anne Hollowed, NMFS/REFM) that enhancements to AOOS (especially better temperature data) could lead to significant improvements in fisheries scientists' ability to accurately predict (on a relative scale) stock sizes and recruitment of major groundfish species.[4] Scientists indicated that constraints imposed within their stock assessment models to account for uncertainty could be reduced and that recommended ABCs would increase significantly for many of the groundfish species. Furthermore if there was a longer track record of improved stock assessments it is surmised that political decisions to limit overall harvests would eventually be removed and that TACs would approach recommended ABCs.

The *Alaska Groundfish Fisheries Final Programmatic Supplemental Environmental Impact Statement (*NMFS, 2004), included an alternative (Alternative 2.1) that utilizes an assumption of greatly improved fishery and oceanographic information (such as might be provided with AOOS) to justify a significantly more aggressive harvesting strategy in the Alaska groundfish fisheries. Specifically, the alternative assesses groundfish harvests under the assumption that uncertainty in stock levels and recruitment are greatly reduced, and that artificial caps on harvests are eliminated.[5]

The quantitative assessment of the various Alternatives included in the SEIS utilized the "North Pacific Multi-Species Management Model" developed by Dr. James Ianelli (2003) to simulate the management of groundfish in the North Pacific (Please see page 4.1–27 of the SEIS (NMFS, 2003) for a summary of the Ianelli model).

We utilized the Ianelli model results from the SEIS to estimate potential increases in fishery values or revenue that might be realized in the Alaska groundfish fisheries if the AOOS were enhanced and or made more readily available to users. Specifically, we assume that improvements in coastal ocean observing systems result in stock assessments that are significantly more accurate, and that scientists are better able to make long range (3–10-year) projections because of the enhanced ability to predict spawning success. This would greatly increase the confidence that scientists, decision makers, and the interested public (including environmentalists) have in the process. In the SEIS, the Ianelli model assumed that as a result of improved information, decision makers can eliminate the 2 million OY Cap in the Bering Sea and Aleutian Islands (BSAI) and allow TAC in both the Gulf of Alaska (GOA) and BSAI to rise to Maximum Sustainable Yield levels. Harvest of groundfish could nearly double under this scenario.

Table 6 shows catch estimates taken directly from pages H-23–H-57 of Appendix H of the SEIS (NMFS, 2003) for FMP 1 (the base case) and for FMP 2.1. Estimates of wholesale value of these catches are based on the 2002 wholesale values per pound imputed from Tables 1 and 2. Note that the wholesale prices estimates were generated assuming no price effect with significantly increased harvests, that is, wholesale prices are assumed perfectly elastic.

The results demonstrate the possibility that with improved information catch and value or revenue in the fisheries may increase significantly. The average change in benefits as

Table 6
Estimated value of improved information in Alaska groundfish fisheries

Year	Base case		With improved information		Difference	
	Catch (lbs. Millions)	Wholesale value ($ Millions)	Catch (lbs. Millions)	Wholesale value ($ Millions)	Catch (lbs. Millions)	Wholesale value ($ Millions)
2003	4,740	1,508	8,651	2,724	3,911	1,216
2004	4,768	1,517	6,895	2,212	2,127	695
2005	4,804	1,525	5,966	1,939	1,162	413
2006	4,526	1,442	5,583	1,823	1,057	382
2007	4,427	1,413	5,653	1,845	1,226	432
5-year avg.	4,653	1,481	6,550	2,109	1,897	628

Sources: Catch estimates are taken from Alaska Groundfish Final Programmatic SEIS. NMFS, 2004, Tables 4–1 through 4–38; estimates of wholesale value are estimated by Northern Economics based on the average wholesale value per ton of harvest from 2002 as shown in Table 2.

measured by an increase in wholesale value projecting out 5 years from the base year (2002) is over $628 million annually (in 2002 dollars). Please note that additional increases in wholesale value may also result from reductions in incidental catch and subsequent discards as well. The model does not measure this affect. However, there would most likely be a price effect resulting from a significant increase in harvest suggesting that our estimate is an over estimate of the true value of increased harvest. In addition, as noted in an earlier section, applying an expected value model using hypothetical probabilities suggests that there might be only a 9% chance that such benefits will in fact ever be realized.

Currently, OOS data is not readily used in Alaskan commercial crab fisheries. Occasionally fisheries managers use weather data to adjust fishing seasons (for safety reasons). In addition, bottom temperature information is sometimes used as an indicator of species distribution and correlated over time to stock size. However, in general, it appears that the greatest benefit to the Alaskan king and Tanner crab industry from enhanced AOOS could be in the long term with the collection of appropriate time series data. Biological and oceanographic data could be correlated with trawl surveys and allow fisheries biologists to better predict crab recruitment and productivity. This information could be used to develop harvest rate models that more accurately reflect the state of the ecosystem.

According to Gordon Kruse (2004) oceanographic conditions (upwelling, temperature, and currents) are critical to the development of larvae for nearly all species of crab. For example, egg and larvae development are temperature sensitive. Larvae feed on phytoplanktons that are light sensitive. If winter/spring is cold then it is likely that phytoplankton blooms will occur before the crab larvae are developmentally ready. Better oceanographic data would allow fisheries scientists and fisheries managers to better predict poor and good recruitment and thus allow for more accurate determinations about when to close and or open a fishery.

It has been suggested that an aggressive harvest policy in the face of uncertainty about recruitment is the primary cause of the collapses of crab fisheries (Kruse, 2004). According to Kruse, successful reproduction of various crab stocks depends not only sufficient numbers of spawning adults, but also on favorable ocean conditions (currents and temperatures in particular). While estimates of spawning adults can be attained using catch data and trawl surveys, ocean conditions linked to successful reproduction are not easily monitored. An enhanced ocean observation program would significantly improve scientists' ability to successfully predict reproduction events.

Kruse suggests that the collapse of king and Tanner stocks over the last decade can be linked to recruitment failures that occurred over several successive years. Even though the spawning biomass was adequate for sustainable harvests, ocean current and temperatures caused reproduction failures. Because new year classes were not being produced as assumed, overfishing resulted. The first major failure occurred in the Kodiak king crab fishery in 1983. By the time scientists realized that recruitment failures were occurring, the stock was fished below minimum stock size thresholds levels from which it has never recovered. In the case of the Bristol Bay king crab collapse, scientists and managers recognized the pattern from Kodiak and scaled back harvests enough to keep the stock above the minimum threshold, and thus the fishery continues albeit at much lower levels.

Kruse believes that an enhanced ocean observation system could have provided scientists with enough additional information that the total closure of the Kodiak king crab fishery could have been avoided. At a minimum, with additional information, a scaled back king crab fishery could have been maintained at levels proportional to current levels in Bristol Bay. Given this feedback from the science community we assume in our analysis that an enhanced ocean observation system could have prevented overfishing in Kodiak and that a Kodiak fishery would exist today.

Figure 3 is a copy of Figure 2 except that hypothetical harvests are assigned to the Kodiak fishery assuming they are proportional (based on peak harvest years) to harvest rates in the Bristol Bay king crab fishery. The heavy dashed line shows projected catches in the Kodiak king crab fishery under the hypothetical scenario that better data on relevant oceanographic parameters could have prevented the collapse of that fishery.

The projected catches in Figure 3 were estimated using a very simple algorithm that assumes that the Kodiak king crab fishery would have continued at levels proportional to the king crab fishery in Bristol Bay based on peak historical harvest levels in the two fisheries. The peak historical harvest in Kodiak occurred in 1965 at 94.4 million pounds, whereas the peak historical harvest in Bristol Bay occurred in 1980 at 129.9 million pounds. Given the peak Kodiak fishery was 72.67% of the peak in the Bristol Bay fishery we project that had better information been available through an enhanced AOOS the Kodiak king crab fishery might have continued at a level 72.67% of the Bristol Bay fishery.

The average hypothetical Kodiak king crab harvest shown in Figure 3 between 1983 (the year following the last year of Kodiak harvests) was 6.4 million pounds. This was multiplied by the estimated ex-vessel price per pound from the 2002 Bristol Bay fishery ($6.14 per pound) and then adjusted by an ex-vessel to wholesale value adjustment factor of 1.57, yielding an estimate of $62 million annual wholesale value (in 2002 dollars) for the Kodiak king crab fishery.

While this estimate is relatively speculative (the collapse of the Kodiak crab fishery cannot be prevented after the fact) it does provide insight into the potential benefits of an enhanced AOOS if information can and is used to inform fisheries management in such as way as to reduce incidents of overfishing.

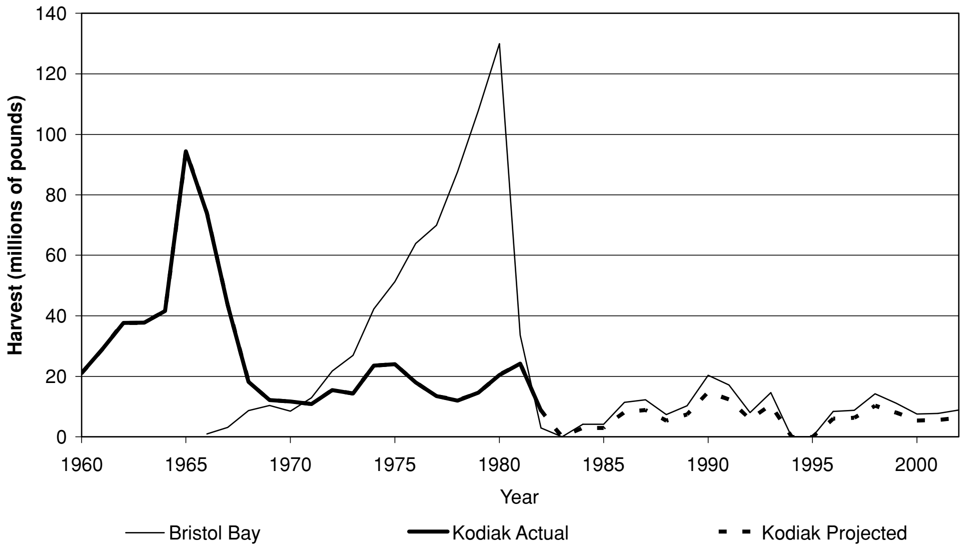

Figure 3. Projected Kodiak King Crab harvests if better information were available. *Source*: Data from *Westward Region Shellfish Report*, 2002. ADF&G. Kodiak Alaska, 2003. Projections of Kodiak from 1982–2002 were developed by Northern Economics.

Conclusions

In general, a fully developed AOOS has the potential to provide fishery managers with the tools to maximize the sustained use of fishery resources. In particular, enhanced data collection and dissemination can reduce the uncertainty (increase confidence) in establishing exploitations rates through, among other things, improved predictions of recruitment failures or successes. It is well known and accepted that errors in forecasts of fish populations are in part due to environmental unknowns. The parameters that appear to be of most interest to fishery stock assessment scientists and managers are upwelling, temperature, currents (including tidal currents), salinity, chlorophyll, and the strength of oceanfronts. These are all factors that affect rates of maturation and migration and are more or less important depending on the fishery in question. In addition, it is felt that more precise[6] data (more data points both spatially throughout the entire North Pacific Rim and temporally) would reduce uncertainty and enhance understanding of fish growth and predictions of productivity and migration patterns and ultimately lead to more efficient harvest management strategies.

We show that an enhanced ocean observation program has the potential to provide significant benefits in terms of revenue generated in Alaska commercial fisheries. In particular better information and higher levels of certainty could allow a more aggressive harvest policy in the Alaska groundfish fisheries without placing stocks under undue risk of overfishing allowing for potential revenue increases. In addition, better information could reduce uncertainty about crab stock recruitment and reduce the potential for fishery collapse and unnecessary revenue losses.

In addition to the aforementioned, it appears that the value of and enhanced AOOS would probably be highest in the rationalized fisheries. Benefits may also be derived from more detailed knowledge of the distribution of fish by age and season, which would allow harvesters to minimize by-catch or catch of non-targeted species (an unintended consequence of harvest but of significant value to society). Finally, there may also be benefits or value from enhanced data collection and dissemination through AOOS to fisheries managers as relates to Essential Fish Habitat Provisions, Marine Protected Areas and marine mammal protection (Terry, 2004). Fisheries managers need and want better data to allow them to deal with the complex spatial and temporal dimensions associated with ecosystem-based management tools that are the underpinnings of the latter fishery management tools.

Notes

1. Estimates of ex-vessel value include an implicit value for fish harvested by vessels that both catch and process groundfish (catcher processors or CPs). In reality there is no monetary transaction of involving raw fish with CPs, and therefore no actual ex-vessel value is recorded. Implicit values are estimated using the prices received for raw fish by catcher vessels when they deliver fish to processors.
2. The State of Alaska has some management authority over Pacific cod and black cod when they are harvested in state waters.
3. This "optimum yield" cap was approved as part of Amendment 1 to the BSAI Groundfish FMP by the Council and the Secretary of Commerce and implemented in 1984 to ensure that fisheries would not be over-harvested.
4. For the past several years stock assessment scientists (Ianelli, 2003) have been evaluating the effect of bottom temperature on annual survey catchability of Pollock. Bottom temperature was collected during the NMFS summer bottom-trawl surveys. It was shown that temperature affects the distribution of Pollock on the shelf and by extension could affect the availability of the stock to survey. That is, temperature may affect the proportion of the stock that is within or outside of the standard survey area. These patterns were further examined by comparing Pollock density with selected on-bottom isotherms. This shows that 2002 was warmer than usual and that, in general, Pollock densities are rare at temperatures lower than 0 degrees. The latter illustrates the significant value of the understanding of the effect of this physical parameter on the evaluation and determination of allowable biological catch in fisheries management.
5. Alternative 2.1 from the SEIS had the following features: (1) ABC is increased to be equivalent to the OFL level, and the F_{OFL} fishing rate is not lowered for stock sizes below $B_{40\%}$.. (2) The BSAI optimum yield range of 1.4–2.0 million mt is removed, and the optimum yield is set to the sum of the individual species OFL levels. (3) Prohibited species catch limits and bycatch limits are removed. (4) Trawl closures and gear restrictions are removed. (5) Fishing is allowed in current closed areas.
6. Some of the North Pacific fisheries scientific community would prefer to have data collected throughout the year by means of an establish grid system of permanent monitoring buoys throughout the Pacific Rim that collect data on currents, temperature, salinity, and chlorophyll (Hollowed, 2004).

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