Management of the Data-Limited Weathervane Scallop Fishery in Alaska

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Abstract

The weathervane scallop *(Patinopecten caurinus)* fishery in Alaska provides a case study of fishery resource management in a data-limited situation. The fishery progressed through several developmental phases since its inception in 1967. During the early years, the fishery was virtually unregulated. Harvests declined by the mid 1970s due to localized depletion of large scallops, establishment of closed areas to protect crabs and their habitats, and loss of product markets. Improved stock conditions and favorable seafood prices led to rapid growth of the fishery and concerns for overfishing in the late 1980s and early 1990s. Prior to 1993, the fishery was passively managed without a management plan. Since the mid 1990s, the fishery has been managed under state and federal fishery management plans (FMPs) that contain a suite of precautionary management measures including a limited entry program that prevents additional capitalization, conservative area-specific catch quotas to safeguard against recruitment overfishing, gear and crew size restrictions in part to prevent growth overfishing, and strict bycatch controls and area closures to minimize adverse fishing effects on large epifauna (e.g., crabs) and their habitats. A small fleet prosecutes the modern fishery; some vessels operate as a fishing cooperative to optimize harvest allocations among

Contribution PP-237 of the Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

participants and minimize operational costs. A mandatory industry-funded onboard observer program collects data for fishery management and assures regulatory compliance. A combination of state, federal, and industry funding supports a small, ongoing research program to address extant data limitations.

Introduction

This paper describes the weathervane scallop *(Patinopecten caurinus)* fishery in Alaska as an evolving case study of fishery management with limited data. There were periods when landings statistics were the only data collected. Even today, there have been no full stock assessments of weathervane scallops in Alaska. Estimates of abundance, and therefore exploitation rates, remain unknown and biological reference points are still being developed. The evolution of this fishery reflects a rather tight coupling between development of data acquisition programs, fishery innovations, and management actions based on new data. Management is complicated by jurisdiction by the State of Alaska in state waters (<5.6 km from the coast) and federal jurisdiction in the exclusive economic zone (5.6-370.4 km offshore). However, even in this regard, state-federal management has evolved over time in attempts to improve efficiency and coordination of management actions. The fishing industry has been active to fund data collection and to help shape the current management regime. The current fishery is believed to be managed conservatively and is prosecuted by a fleet that is not overcapitalized. However, the colorful history of this scallop fishery includes the stages of development typical of most fisheries: discovery, bandwagon growth, fallback, and evolutionary development (Walters 1986). Kaiser (1986), Kruse (1994), Kruse and Shirley (1994a), Shirley and Kruse (1995), Kruse et al. (2000), Turk (2000), and Barnhart (2003) reviewed various aspects of scallop fishery history in Alaska. From these accounts we synthesize the interconnections among historical fishery development, chronology of management actions, and evolution of data collection methods to reduce levels of data limitation.

Weathervane scallops are distributed along the west coast of North America from central California to the eastern Bering Sea, and west to the Aleutian Islands (Foster 1991). Their depth distribution spans 0-300 m, but commercial densities generally occur at 46-128 m (Ronholt et al. 1977) on discrete beds, typically oriented with bottom currents that parallel bathymetry (Fig. 1). Beds may be composed of a wide range of substrates (Hennick 1973), but spatial analysis of sediment charts and fishing effort data indicates that scallop beds are typically associated with clayey silt, sand, and gravely sand sediments (Turk 2000). Most scallops mature at 76 mm shell height (SH), which is attained by age 3 or 4 years depending on area (Hennick 1970, Kaiser 1986, Ignell and Haynes 2000). The largest recorded Alaska specimen measured 240 mm SH with an

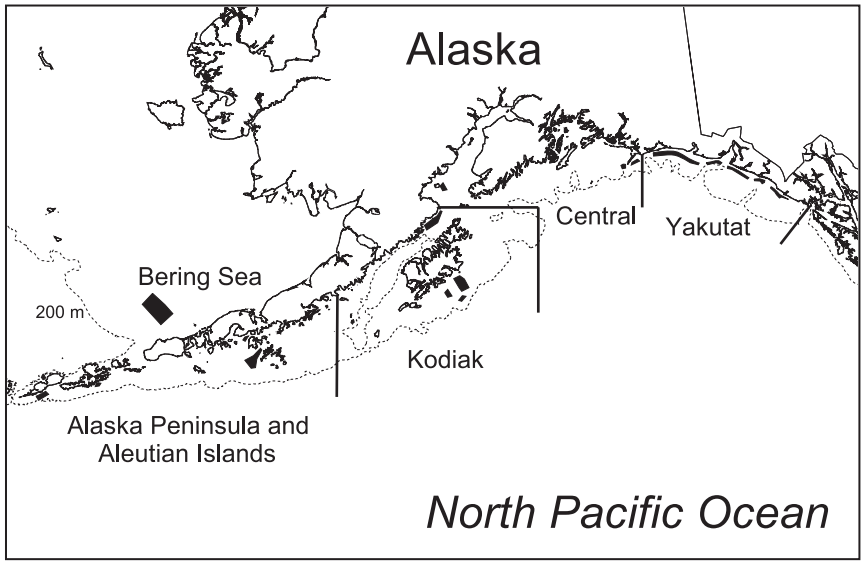

Figure 1. Map of the principal fishing grounds for weathervane scallops (solid black) in the Gulf of Alaska, Aleutian Islands, and Bering Sea, as indicated from onboard observer data. Small vessels without observers also harvest weathervane scallops from beds in Kamishak Bay, an embayment north of Kodiak Island on the western side of lower Cook Inlet in the central region. The dotted line shows the 200 m isobath.

adductor meat weight of 340 g, and the oldest specimen was 28 years old (Hennick 1973). Estimates of instantaneous natural mortality (M) range from 0.04 to 0.25, with median of 0.16, corresponding to 15% annual mortality (Kruse 1994).

In the current fishery, weathervane scallops are generally harvested by vessels towing two New Bedford style dredges. Dredges consist of a rectangular metal frame, typically 4.57 m wide weighing 1,180 kg (Barnhart 2003). An exception is a small scallop fishery in lower Cook Inlet where vessels are required to use a single 1.8 m dredge weighing 408 kg. Steel "shoes" on lower corners of the frame serve as runners on the seafloor. Attached to the frame is a bag made of 10.16 cm steel rings connected by chain links. A sweep chain footrope is affixed to the bottom of the bag. The top of the bag is composed of 15.24 cm polypropylene stretched mesh. A "club stick" (metal bar) is attached to the end of the bag to retain the shape of the ring bag and provide an attachment point for lifting and emptying its contents.

Weathervane scallops are shucked; only the single adductor muscle is retained. Scallop meats are 8-12% of total live weight, depending on area and season (Barnhart and Rosenkranz 2003). Meats are graded by size and sold to domestic seafood markets. Early attempts to market scallop mantles and gonads were unsuccessful, and even today a product with roe, which is highly desirable in European markets for some other scallop species, is not prepared from weathervane scallops partly due to concerns about paralytic shellfish poisoning in Alaska.

Fishery history

Initial fishery development (1967-1973)

The U.S. Bureau of Commercial Fisheries (later named National Marine Fisheries Service, NMFS) explored the distribution of weathervane scallops in Alaska during periodic surveys since 1953 (see Table 1 in Haynes and Powell 1968 and Appendix 3 in Turk 2000). Beds were located by scallop dredge surveys and analysis of scallop bycatch from groundfish trawl surveys. Despite these early efforts, it was not until 1967 that loss of fishing opportunities associated with declines of red king crab *(Paralithodes camtschaticus)* catches led to the first establishment of a small fishery (2 vessels) off Kodiak. During 1967 and part of 1968, scallops were delivered live to shoreside processors; however, this proved uneconomical and scallopers began delivering shucked scallop meats to processors for packaging and freezing (Kaiser 1986). In 1968, 19 vessels harvested 761 metric tons of scallop meats from the Yakutat and Kodiak management areas combined (Fig. 2). The fleet included numerous vessel types, including specialized vessels from New England and Alaskan fishing vessels converted from fisheries for crabs (pots), salmon seiners and gillnetters, halibut longliners, and shrimp trawlers (Kaiser 1986). The fishery peaked in 1969, when 19 vessels harvested 839 t of scallop meats. Thereafter, interest in the fishery began to wane perhaps due to a combination of weaker markets, high operating costs, and loss of crews who were attracted to higher paying jobs with the construction of the Alaska oil pipeline (Turk 2000). During 1970-1973, just 5-7 vessels landed an average of 527 t annually. Those remaining in the fleet were the most efficient vessels with capabilities to fish both in the day and night—vessels that measured 27-30.5 m in length and towed two 3.7-4.3 m wide dredges weighing 725-910 kg each (Hennick 1973). Shucked scallops were washed, placed in 18 kg cloth bags, and iced in the vessel's hold. During these early years, all scallop fishing was confined to the Kodiak and Yakutat areas, and catches were delivered to shoreside plants in Kodiak and Seward, Alaska.

Commercial landings statistics were collected since the inception of the fishery. Early data were limited to landings statistics, except during 1969-1972 when a small voluntary observer program involved a few

cooperating vessels (Hennick 1973). Observer data included age, sex, maturity, size, fishing area, days fished, catch rate, tow length, depth, bottom type, catch and bycatch, and damage to caught species. These data showed that the percentage of scallops ≥7 years old in the catch declined from 74%-96% in 1968-1970 to 39%-71% in 1971-1972, reflecting the typical fishing-up effect (Walters 1986). Observer data showed that Dungeness crab *(Cancer magister)* appeared seldom as bycatch. One to four red king crab were caught per tow, and these rates varied by area (none off Yakutat) and season (highest in spring when king crabs migrate inshore to molt and mate). An average of 20-40 small (2.5-8 cm carapace width) Tanner crabs *(Chionoecetes bairdi)* were caught per tow (Hennick 1973).

From its inception, the Alaska weathervane scallop fishery was managed by the State of Alaska. During 1967-1968, no areas were closed to fishing, all gear types were allowed, and the only regulatory requirements were the purchase of a vessel license and commercial fishing license (Kaiser 1986). Although some concerns were expressed about harvest levels as early as 1970, most management concerns revolved around potential fishing effects on bycatch of fish, other shellfish, and their habitats. In 1969, the state regulatory body, Alaska Board of Fisheries (BOF), created time and area closures in selected waters off Kodiak Island and the Alaska Peninsula to protect molting and mating king and Tanner crabs. Regulations were based on crab bycatch data collected by observers. These regulations were renewed and modified annually until a June 1–March 31 scallop fishing season was established in 1971 for portions of the Kodiak fishing district. Few regulations were imposed in other areas of the state, except for portions of Cook Inlet where seasons and closed waters were also established. Gear was restricted to longlines, trawls, and dredges, and after June 1, 1969, dredges were required to have rings ≥102 mm diameter (Kaiser 1986).

Fallback phase (1974-1979)

The fishery steadily declined after 1973 (Fig. 2). Landings averaged just 139 t during 1974-1977 and no landings were reported in 1978. All harvests were taken near Kodiak and Yakutat. The geographic range of fishing trips was limited because fresh scallops were accepted only if they were caught less than 10 days prior to delivery; portions of catches were often discarded due to decomposition (Turk 2000). In the early to mid 1970s, vessels conducted numerous, generally unsuccessful, exploratory cruises in attempts to boost landings to prior levels (Hennick 1973). The decline in this period of the fishery was attributed to multiple causes: (1) area closures and season restrictions that reduced fishing opportunities; (2) limited distribution of scallop beds off Kodiak and Yakutat; (3) unreliable and generally declining prices paid by processors for landed

Table 1. Links among fishery managment, data acquisition, and weathervane scallop fishery developmental stages during 1967-2002.

Year	Management action	Data acquisition	Fishery stage
1953-1966	No fishery management plan (FMP).	Relative abundance and distribution from surveys.	None.
1967	Agencies promote fishery development.	Landings database (fish tickets) initiated.	First small commercial landings off Kodiak.
1968-1972	State management begins. Passive regulations include gear, seasons, and closed areas.	One survey and small onboard sampling program collect age, shell height, weight, size at maturity, meat recovery, and bycatch.	Full fishery develops off Kodiak and Yakutat, scallops depleted from fished beds, vessels decline from 19 to 5.
1973-1978	No new action.	Surveys and sampling programs discontinued.	Landings, CPUE, and vessels decline to zero in 1978.
1979-1989	No new action.	Fish ticket data (only) continues. First survey conducted in Kamishak Bay (1984).	Fishery re-develops and expands to SE Alaska, Cook Inlet, Aleut. Is. and Bering Sea. Mean vessel size increases.
1990-1993	High-impact emerging fishery declared. State adopts interim FMP (1993), including crew limits, crab bycatch limits. Shucking machines banned.	Mandatory industry-funded onboard observer program starts (1993). Data collected on age, shell height, weight, meat recovery, and bycatch. Early emphasis on crab injuries in bycatch.	Catches escalate, first catches from Prince William Sound, vessel and crew sizes increase, overfishing concerns for some areas.
1994	State adopts FMP, including registration areas, area-specific guideline harvest ranges (GHRs), new gear restrictions, and fishing seasons.	Fishery economic data studied for possible vessel moratorium.	Fishery considered as overcapitalized.

Table 1. (Continued.)

Year	Management action	Data acquisition	Fishery stage
1995	NMFS adopts emergency rule and federal FMP closes fishery.	Scallop survey conducted off Kayak Island (PWS).	1 vessel does not register, avoids state regulations, and catch is 200% of GHR in PWS.
1996	FMP Amendment 1 approved, federal regulations parallel state regulations.	Routine surveys resumed in Kamishak Bay and Kayak Island.	Fishery resumes. Bering Sea harvest is constrained by bycatch caps.
1997	FMP Amendment 2 (vessel moratorium for federal waters) established, and vessel moratorium established for state waters.	No change.	18 vessels qualify, harvest stabilizes at about half of highs.
1998	FMP Amendment 3 approved, management delegated to state. FMP Amendment 6 (definition of overfishing, MSY, and OY) approved.	No change.	Overall landings stable.
1999	FMP Amendment 5 (essential fish habitat) approved.	No change.	Overall landings stable.
2000	FMP Amendment 4 (license limitation program) approved.	Age-structured assessment model developed for Kamishak Bay.	7 vessels participate, fishing cooperative formed by industry.
2001	No change.	Establishment of a pilot video stock assessment program.	Participation falls to 6 total vessels, not all GHR harvested.

FMP = fishery management plan.
GHR = guideline harvest range.
MSY = maximum sustainable yield.
OY = optimum yield.
PWS = Prince William Sound.

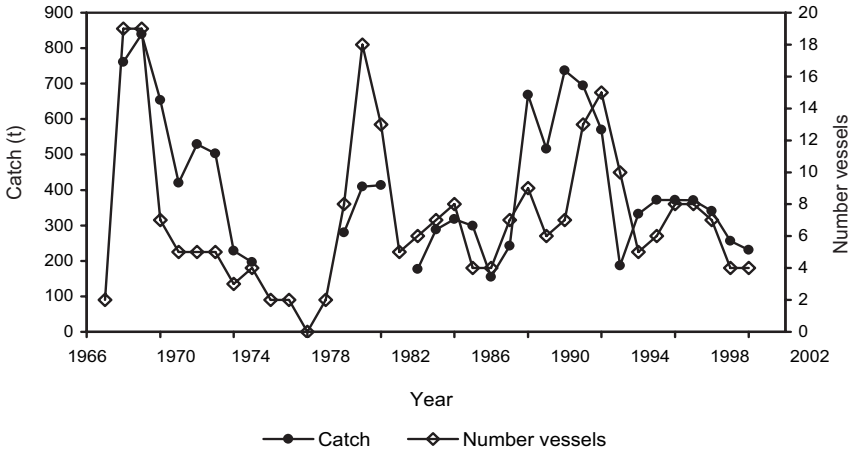

Figure 2. Numbers of participating vessels and reported landings (metric tons) of weathervane scallop meats in Alaska during 1967-2002. Scallop meats account for approximately 8-12% of the total (round) weight of harvested scallops, depending on area and season (Barnhart and Rosenkranz 2003). Landings are confidential and are not shown in years when fewer than three vessels participated in the fishery.

scallops in the early to mid 1970s (Fig. 3); and (4) increasing operational costs (Kaiser 1986).

Aside from landings statistics, virtually no biological and fishery data were collected during 1973-1978, a severely data-limited period. The observer program was discontinued owing to limited agency funding. Age composition data are unavailable, with the exception of one sample from the east side of Kodiak in 1975 which showed the continued predominance of young scallops (Kaiser 1986). In 1979, limited size composition data were collected, and catch rates were similar to previous historical averages (Kaiser 1986).

During 1973 and 1975, the BOF closed additional areas near Kodiak to scallop dredging, and fishing seasons were shortened to July 16–March 31 to afford greater protection to molting and mating crabs in late spring–early summer (Barnhart 2003). However, other portions of the Kodiak area and other areas of the state remained open to scallop dredging year-round.

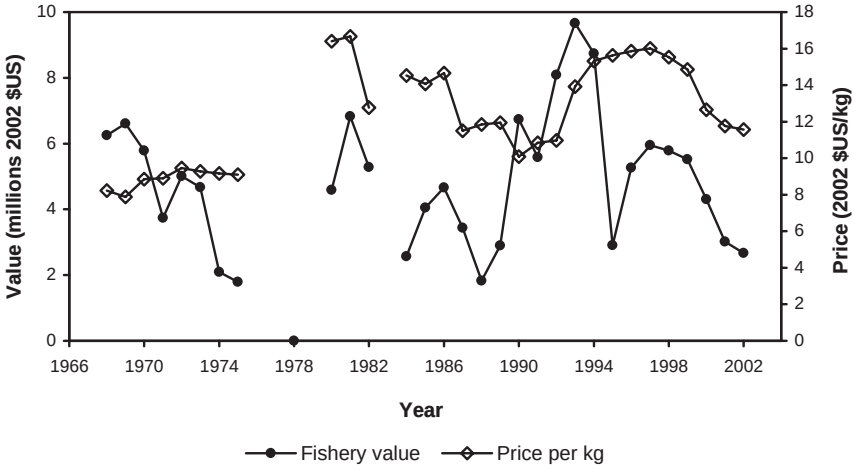

Figure 3. Estimated landed value and ex-vessel price (price paid to fishermen by processors) of weathervane scallops in Alaska during 1967-2002. Value and price have been adjusted to 2002 dollars based on the Consumer Price Index–Urban Research Series available from the U.S. Department of Labor, Bureau of Labor Statistics. Landings are confidential and are not shown in years when fewer than three vessels participated in the fishery.

Redevelopment phase (1980-1989)

Renewed interest in the Alaskan weathervane scallop fishery in the 1980s was partly attributed to both significantly improved prices (Fig. 3) and the overcapitalized Atlantic sea scallop *(Placopecten magellanicus)* fishery in New England, where numbers of U.S. vessels increased from 44 to 200 during 1975-1979 and landings declined 22% over 1978-1981 (NEFMC 1982). These same factors led to a boom-bust fishery off the Oregon coast in which 532 t of scallop meats were harvested in 1981 by 118 vessels; approximately 20 of these vessels were nonresident (Starr and McCrae 1983). Subsequent Oregon landings have been very small (Bourne 1991). During 1980-1983, Alaska landings increased from 280 t to 414 t in 1980-1982 (Fig. 3) despite declining participation (18 to 5 vessels). During 1984-1989, an average of 6 vessels delivered 247 t annually.

Vessels became increasingly specialized (Shirley and Kruse 1995). In 1983, vessels earned 60% of their incomes from scallops, the remainder coming from landings of crabs, shrimps, clams, herring, salmon, halibut, and other groundfish. By 1989 scallops accounted for 85% of total fishery earnings by vessels participating in the scallop fishery. Mean vessel size

increased; during 1983-1987, the percentage of small (<18 m), medium (18-31 m), and large (>31 m) vessels averaged 49%, 34%, and 17%, respectively (Kruse and Shirley 1994b). By 1988-1989, there were 64% medium and 36% large vessels with no small vessel participation.

In the 1980s, harvests were first taken from areas outside of Yakutat and Kodiak including Southeast Alaska (1980), Alaska Peninsula and Dutch Harbor (1982), Cook Inlet (1983), and Bering Sea (1987). During the 1980s, Kodiak scallop beds still contributed most (44%) to statewide harvest, followed by the combined Alaska Peninsula–Aleutian Islands (mainly Dutch Harbor and Adak) areas (31%), Yakutat (22%), Bering Sea (2%), and the central region (1%), composed of Prince William Sound (near Kayak Island) and Kamishak Bay (west side of lower Cook Inlet). The fishery was lucrative. Mean landings and ex-vessel value (i.e., the price paid for fishery landings) of scallops per vessel increased from 35.0 t worth US$0.57 million in 1980 to 74.7 t worth US$0.86 million in 1987. Through the 1980s, scallop fishermen continued to ice scallop meats in 18 kg bags for delivery to shoreside processors for freezing and distribution (Turk 2000). Scallop product quality and prices remained variable owing to the length of fishing trips. Mean (inflation-adjusted to 2002) prices declined from $16.40 per kg in 1980 to $11.95 per kg in 1989.

The years 1980-1989 were severely data limited—only fish tickets (i.e., records of landings purchased by processors from fishermen) and commercial operators' annual reports (i.e., annual reports submitted by seafood processors which include processed product forms and seafood prices) were collected with one exception. In 1984, the first ADFG scallop survey was conducted in Kamishak Bay. The Alaska fishery remained passively managed with miscellaneous regulations concerning gear, fishing seasons, and closed areas. All Alaska waters were managed as a single registration area.

Bandwagon growth phase (1990-1993)

Harvests tripled from a mean of 224 t per year in 1983-1989 to 649 t per year in 1990-1993. The 1992 harvest of 737 t, worth US$8.1 million (2002 dollars), was the second largest in the history of the fishery. That year, mean ex-vessel value of scallop landings exceeded $1 million per vessel. The 1993 harvest of 694 t worth $9.7 million (2002 dollars) was the most valuable in the history of the fishery to date. During 1990-1993, participation increased from 9 to 15 vessels. Vessels were fully specialized, earning 100% of their fishery incomes from scallops (Kruse and Shirley 1994b). Mean vessel size increased 85% from 18.5 m in 1983 to 34.3 m in 1991 (Shirley and Kruse 1995). As vessels became larger and more specialized, crew sizes increased. In the early 1980s average crew sizes were 5-8 persons depending on area, but by 1993 all vessels except the smallest carried 12-person crews (Shirley and Kruse 1995). Automatic shucking machines were first used in 1991. Automatic shuck-

ing machines and larger crews facilitated economical processing of small scallops (Kruse and Shirley 1994b). During 1990-1993, most vessels installed onboard freezing operations to assure consistent, high-quality product. Partly as a result, ex-vessel prices increased $1 per kg during these three years.

As fishing effort shifted to new areas and harvests approached historical highs that were not sustained, conservation concerns developed. In 1992, ADFG released a draft interim FMP for public comment (Kruse et al. 1992). In 1993, ADFG declared the fishery to be a "high impact emerging fishery"—a State of Alaska designation applicable when at least one of four conditions are met: (1) harvesting effort recently increased beyond a low sporadic level; (2) the resource is harvested by more than one user group; (3) harvests approach levels that may not be sustainable; and (4) the BOF has not developed comprehensive regulations to address conservation and allocation issues. ADFG found that these conditions applied.

The interim FMP included a broad goal to maximize overall long-term benefits of scallop resources, while providing for conservation of scallop populations and their habitats. Five objectives were to: (1) ensure long-term viability of scallop populations; (2) minimize adverse effects on benthic species and habitats; (3) ensure conduct of manageable, steady-paced scallop fisheries that provide stable employment and supplies of high-quality products to seafood markets; (4) ensure harvest requirements of traditional users in coastal communities; and (5) gather new data relevant to attaining other objectives (Kruse et al. 1992). Key provisions of the interim FMP and subsequent BOF actions included: (1) establishment of eight (later became nine) separate registration areas; (2) reporting requirements; (3) gear specifications that limit dredge width ≤4.57 m and rings ≥10.16 cm inside diameter; (4) guideline harvest ranges (catch limits) with upper bounds based on long-term average catch excluding extreme highs and lows; (5) bycatch caps for red king crab and Tanner crab based on 1% of assessed crab abundance if the crab fishery was conducted or 0.5% if the crab fishery was closed owing to low crab abundance; (6) in-season adjustments, which allow managers flexibility to adjust to unforeseen circumstances; (7) closed waters to avoid crab bycatch and sensitive habitats; (8) fishing seasons; (9) observer requirements in which all scallop vessels (except small vessels fishing in lower Cook Inlet) are required to carry an observer at their expense; (10) a limit of 12 crew members per vessel; and (11) a ban on automatic shucking machines.

Some fishery participants were concerned about escalating fishing effort. At the time, the State of Alaska's Commercial Fisheries Entry Commission could limit participants, but not numbers of vessels. The North Pacific Fishery Management Council (NPFMC) can limit vessels in federal waters. Because vessel limitation was the preferred method, in 1993 the NPFMC prepared options for limited access considerations. At

the same time, the NPFMC began to analyze the need for federal FMP for this fishery.

Fishery rationalization phase (1994-present)

Statewide landings of scallops were 570 t in 1994, fell to 186 t in 1995, averaged 358 t during 1996-2000, and averaged 244 t in 2001-2002 (Fig. 2). Prices were high, averaging $15.67 per kg (2002 dollars) during 1994-1998, but declined to $11.57 per kg in 2001-2002 (Fig. 3). Ex-vessel value was $8.7 million (2002 dollars) in 1994, dipped to $2.9 million in 1995, averaged $5.4 million over 1996-2000, and fell to $2.7 million in 2002 (Fig. 3). Statewide landings during 1994-2002 were taken primarily from Kodiak (35%), Yakutat (31%), and the Bering Sea (22%), with smaller amounts from the Alaska Peninsula–Aleutian Islands area (6%), and central region (6%).

In 1994, the state's BOF adopted a scallop FMP (Kruse 1994) largely patterned after the interim plan. The coordinated development of this state management plan and federal plan for license limitation was interrupted in 1995, when one vessel (F/V *Mister Big*) relinquished its state fishing permit and continued fishing outside state waters (>5.6 km) off Kayak Island (northeastern Gulf of Alaska) after the annual guideline harvest range was already taken for the area. Previously, all vessels fishing in state and federal waters were presumed to be subject to state regulations while fishing under a state fishing permit. As the F/V *Mister Big* no longer held a state permit, it continued to fish without regulation, thus challenging state authority over the fishery. Concerned about unregulated harvest in excess of the prescribed sustainable harvest for the area, the NPFMC met in emergency session and NMFS was requested to implement an emergency rule to close all federal waters to scallop fishing so as to temporarily close the loophole in state jurisdiction. Later that year, the NPFMC adopted a federal FMP (NPFMC 1995a), which formalized the closure of federal waters to scallop fishing. With this safeguard in place, some state waters were open in 1995, but most harvest was confined to Yakutat where catch rates were sufficiently high in state waters to warrant interest. Federal waters remained closed for 1.5 years during February 13, 1995–August 1, 1996. Thus, the F/V *Mister Big*, which relinquished its state license, was banned from fishing during this period.

Following the approval of the first federal FMP that closed federal waters to scallop fishing, six amendments to the federal FMP were approved during 1996-2000. In 1996, Amendment 1 adopted federal regulations parallel to those adopted by the state (NPFMC 1997). In 1997, Amendment 2 established a vessel moratorium in which 18 vessels qualified (NPFMC 1997). In that same year, by special action of the Alaska Legislature, a state-waters moratorium was established that qualified 10 vessels. In 1998, Amendment 3 to the federal FMP effectively delegated scallop fishery management to the State of Alaska (NPFMC 1998). The fishery

was deemed to be overcapitalized in 1993 when 15 vessels participated (NPFMC 1995b). In 2000, Amendment 4 was approved, creating a license limitation program (NPFMC 2000). Seven vessels were permitted to fish statewide (except Cook Inlet) and two other vessels were permitted for Cook Inlet. These two small vessels are currently exempted from onboard observer requirements, but they are required to submit logbooks and they are limited to a single 1.83 m dredge. Notably, the F/V *Mister Big* was not among the nine licensed vessels. Finally, plan Amendments 5 and 6 satisfied recent federal requirements for designations of essential fish habitat and definition of overfishing (NPFMC 1999a,b).

Independently, most vessel owners formed a fishery cooperative in 2000. Within the cooperative, owners are allocated shares based on fishing history. Some owners arranged to have their shares harvested by other members and removed their vessels from the fishery. This further reduced fishing effort (just 4 of 7 cooperative vessels fished in 2001-2002), and extended the fishery for remaining participants. This action allows close coordination with fishery managers to precisely attain catch limits. Also, cooperative members are proactive in employing measures to reduce crab bycatch. Vessel operators provide confidential data to third-party consultants who review catch, bycatch, and location data and identify high crab bycatch areas. Near real-time analyses are provided back to the fleet, so they can adjust their operations to avoid triggering premature closures due to bycatch. An unforeseen side effect of effort reduction measures is that fishing capacity was too low in 2001 and 2002 to attain guideline harvests before regulatory fishing season closure dates that are set to protect molting and mating crabs. In part, this resulted from market-related decisions by the fleet. One vessel splits its fishing effort between scallops and the lucrative Bering Sea crab fishery. Also, in summer and early fall the small fleet tends to fish in the western Gulf of Alaska, where large, high-quality scallops command the best prices. Later, after catch quotas in the western gulf have been taken, the fleet moves to the central and eastern gulf. However, by then late fall and winter storms limit fishing opportunities and this region of the coast affords few places for vessels to hide from storms. As a result of these factors, an annual average of about 45 t of catch quota was not harvested from the eastern Gulf of Alaska in 2001 and 2002.

Since 1993, the imposition of an onboard observer program led to a marked increase in data collection from this fishery. Unlike the voluntary observer program on a few vessels in the early years of the fishery, this new program is mandatory and funded at the vessel owner's expense for all vessels fishing outside of Cook Inlet. Observers obtain data on scallop age, shell height, weight, meat recovery, and bycatch. As part of this observer program, vessel operators maintain logbooks with haul locations, tow duration, tow speed, bottom depth, and catch of retained scallops. These data have afforded analyses on bycatch, condition of discarded

crabs and halibut, catch rates, and finer resolution of the location of the harvest (e.g., Barnhart 2003, Barnhart and Rosenkranz 2003). Detailed observer data allowed industry-funded analyses of scallop-habitat associations and preliminary biomass estimates using depletion estimators (Turk 2000).

Also, ADFG conducted fishery-independent assessment surveys in Kamishak Bay in 1996, 1998, and 1999, and near Kayak Island in 1996, 1998, and 2000 (e.g., Bechtol 2003, Bechtol and Gustafson 2002) using a research dredge donated by the Kodiak Fish Company. An age-structured stock assessment model was developed for the Kamishak Bay stock (Bechtol 2000), but time series of age data are too short to apply this model to other Alaskan scallop stocks at the present time.

Beyond routine stock assessment and fishery monitoring, federal funding supported recent applied research by ADFG into genetic stock structure, age validation, and development of video stock assessment technology. To date, analyses of allozyme variability and preliminary analyses of mitochondrial DNA (mtDNA) variability do not suggest much genetic differentiation among scallop beds within Alaska (James Seeb, Alaska Department of Fish and Game, Nov. 2004, pers. comm.). Recently, single nucleotide polymorphisms (SNP) in both mitochondrial and nuclear genes were identified for weathervane scallops (Elfstrom et al. 2005). These SNP developments, together with a full investigation of mtDNA variability, may be useful for delineating scallop population structure for refinement of stock boundaries. Regarding age validation, analyses of oxygen isotope ratios from samples off Kodiak confirmed that checks are formed on scallop valves annually in November-December (Barnhart and Carpenter 2003). Checks seem to be formed during the warmest months of the year associated with intense coastal downwelling. Two scallop fishing vessels have been equipped since 2003 with data loggers to verify seasonal temperature profiles on scallop beds relative to annual check formation. Pilot video stock assessments were conducted in the eastern Gulf of Alaska in 2002 using a towed sled equipped with a miniature video camcorder (Rosenkranz and Byersdorfer 2004). The sled was successfully deployed at 135 stations and over 12,000 scallops were enumerated from 124,000 m^2 of seafloor. These methods contrast with those of Stokesbury (2002), who used a video drop camera to survey *Placopecten magellanicus* on Georges Bank (U.S. East Coast). This video drop camera was attempted in Alaska, but scallop densities were too low and 90% of the drops contained no scallops. However, dredge video surveys were found to be a viable assessment approach for weathervane scallops, and routine surveys are planned for the three most commercially important fishing grounds in Alaska.

Conclusions

The Alaskan weathervane scallop fishery underwent a major transformation from a self-regulated, passively managed fishery in the 1970s to a very actively managed fishery highly constrained by regulations designed to maintain fishery sustainability and reduce adverse dredging effects on other benthic species and habitats. Limited access and formation of a scallop industry cooperative have been key to maintaining a lucrative fishery for the few remaining participants. Mean gross earnings per vessel during 2000-2002 were $0.6-$0.8 million (2002 dollars). Excellent cooperation among industry and fishery managers has been essential to attain harvest guidelines while minimizing bycatch.

Data availability also changed markedly since fishery inception. After an initial data collection program in the late 1960s to early 1970s, virtually no data were collected in the 1980s. Today, catch and bycatch of vessels are well documented by onboard observers. These data are used to set preseason harvest levels as well as for in-season fishery management. Two scallop stocks (Kamishak Bay and Kayak Island) are assessed by fishery-independent dredge surveys, and collection of specimens for age and growth studies is at an all-time high.

Several key data limitations remain, but the outlook for further improvements is promising. Lack of data has prevented a full stock assessment of major commercial scallop stocks. New video assessment technology should not only extend the current small assessment program, but should also allow estimation of dredge catchability, a critical parameter for stock assessments. Also, the continued accumulation of time series of age and size distribution data will allow broader application of age-structured assessment models (e.g., Bechtol 2000) to scallop stocks in Alaska. Moreover, these same time series will permit analyses of recruitment, growth, and mortality so that biological reference points, such as spawning stock biomass per recruit and minimum stock size thresholds, can be incorporated into the harvest strategies. An ultimate goal is to implement biomass-based exploitation rates.

The current level of data collection would not be possible without the cooperative efforts of government agencies and the fishing industry. The industry has funded graduate student projects (e.g., Turk 2000), purchased survey gear for ADFG, and funds the onboard observer program. In 2002, the annual cost of the observer program was about $161,000, roughly 6% of the $2.67 million in ex-vessel fishery value that year. State and federal funds cover the costs of ADFG's scallop research and management program with an annual cost of about $400,000 in 2002. These combined costs, though relatively expensive compared to the value of this small fishery, are investments to attain fishery management goals and objectives.

Acknowledgments

We are grateful to Susan Shirley and two anonymous reviewers for helpful comments on a draft of this paper.

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