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ABSTRACT: The Kvichak River of Bristol Bay, Alaska, is one of the world's largest sockeye salmon producing systems. This paper reviews and documents past management practices for the Kvichak River sockeye salmon. Fishery harvests are managed to meet a biological spawning escapement goal set by the State of Alaska and regulated using management plans adopted by the Alaska Board of Fisheries. Several measures of inseason run abundance are used to determine time and area of fishery openings that allow the escapement goal to be met and ensure that escapement is obtained throughout the run. Returns to the Kvichak River have been relatively small for seven of the past eight years. To hasten rebuilding of this run, the Alaska Board of Fisheries implemented additional management plans in 2001 that limit incidental harvests of Kvichak River sockeye salmon. These restrictions were effective in decreasing the catch of Kvichak River sockeye salmon, but total escapements achieved in 2002 and 2003 were still below the lower end of the escapement goals thought to produce the greatest catches in the future. While small runs and resulting low escapement levels have restricted commercial and sport fishery harvests, sustainability of this sockeye salmon run does not appear threatened at this time. The escapement goal for the Kvichak River is set at a level that provides the greatest potential for obtaining maximum sustained yield. While it is unlikely that escapements below the goal will provide high yields, past performance of low escapements has demonstrated that the Kvichak River run is still sustainable and has the capacity to produce large returns when conditions are favorable.

INTRODUCTION

The Bristol Bay, Alaska commercial salmon fishery is the largest sockeye salmon *Oncorhynchus nerka* fishery in the world and is unique in both origin of the stocks and management of the fishery. Combined annual sockeye salmon runs to the area have averaged 39 million fish for the last 10 years, with nine river systems producing approximately 98% of all returning sockeye salmon: Kvichak, Alagnak, Naknek, Egegik, Ugashik, Togiak, Wood, Igushik, and Nushagak Rivers (Figure 1, Figure 2). Historically, the Kvichak stock was the largest contributor to the harvest. The Kvichak stock has historically had a 5-year cycle with individual years labeled as: peak, pre-peak and off-cycle years. The largest recorded total return was 48 million in 1965, a peak cycle year. However, during the most recent 10-year period, the Kvichak stock has not met its Biological Escapement Goal (BEG) on six occasions and the total return in each of those six years never exceeded 3.6 million. This paper describes the State of Alaska, Department of Fish and Game (ADF&G) management program for the Bristol Bay commercial fishery, with specific emphasis on the Kvichak stock and its failure to achieve the BEG in recent years.

OVERVIEW

The Bristol Bay commercial fishery is managed by the ADF&G, using regulations and management plans adopted by the Alaska Board of Fisheries (BOF). The primary management objective is to meet each river system's BEG. The BEG is defined as the escapement estimated to produce a maximum sustained yield (MSY). Each BEG is based on spawner–recruit data and other ancillary information that may be available. Escapement goals are reviewed and analyzed triennially by a panel of ADF&G biologists and outside experts. Emphasis on achieving spawning escapement goals is intended to ensure that each run is sustained, even through periods of reduced production. Unfortunately, setting a BEG for the Kvichak River sockeye salmon run has proven difficult because of divergence in productivity between cycle years and off-cycle years, poor density dependence in spawner–recruit data, and a lack of fit for Ricker type spawner–recruit curves. The ADF&G primarily manages commercial harvests by determining where and when fishing can occur. The BOF has also provided ADF&G with special authority to adjust fishing methods and fishing area boundaries during the season. Five commercial fishing

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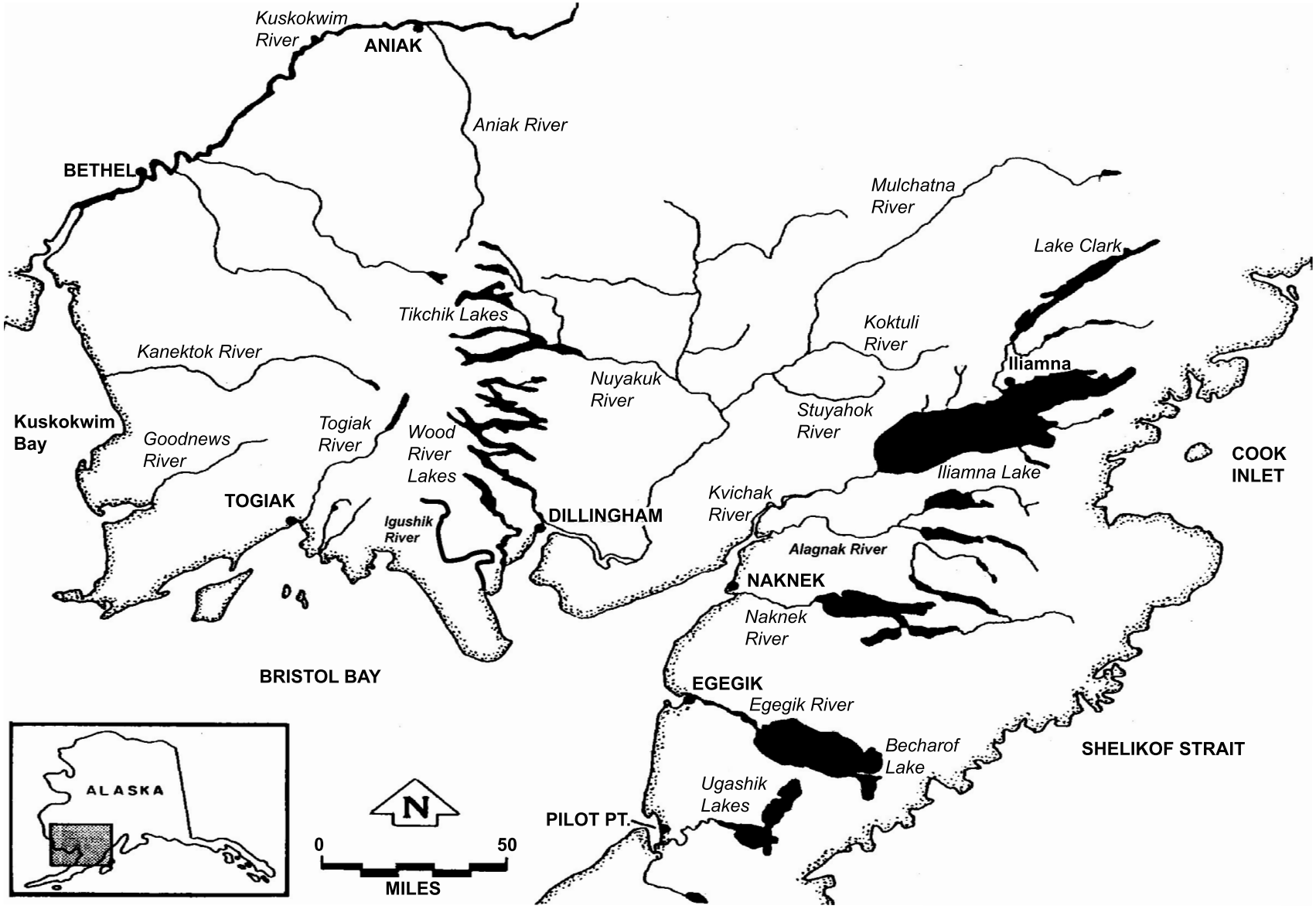

Figure 1. The major sockeye salmon producing river systems in Bristol Bay, Alaska.

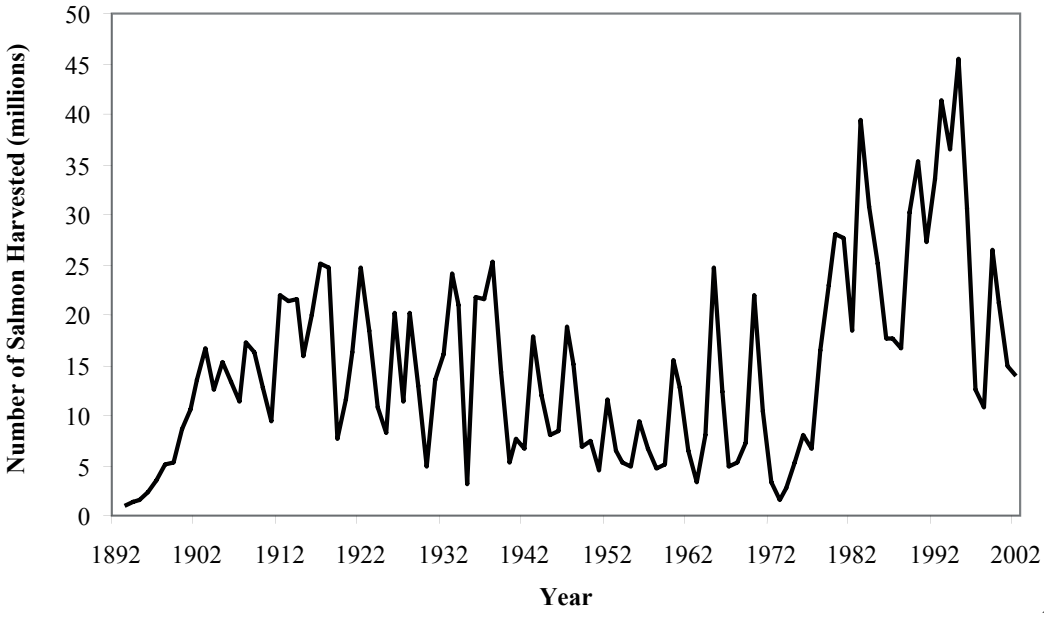

Figure 2. Bristol Bay salmon harvests from 1893 to 2002.

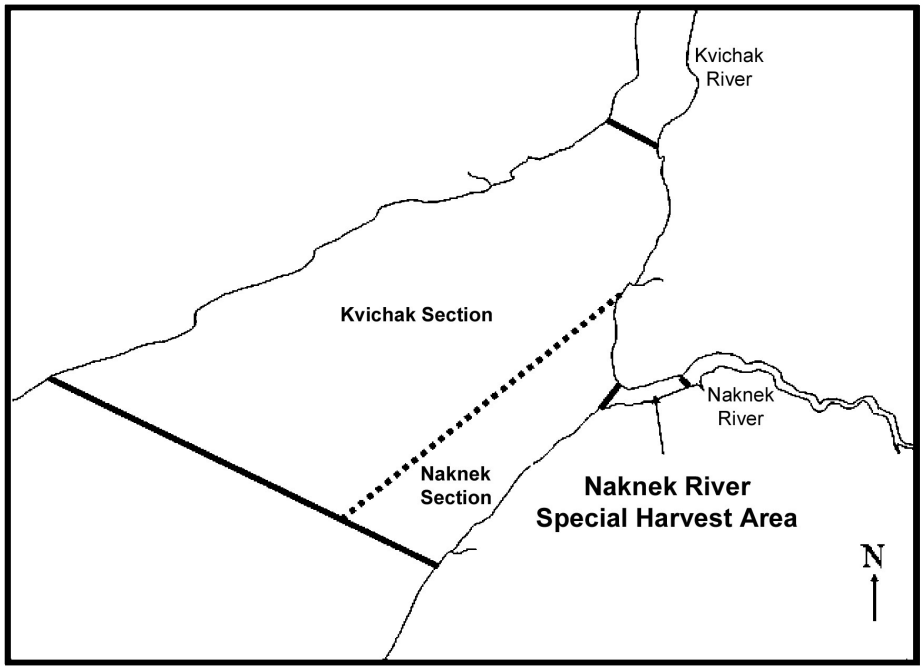

Figure 3. The Naknek-Kvichak fishing district, Bristol Bay, Alaska.

districts have been established in the Bristol Bay management area to focus commercial harvests of Pacific salmon runs returning to specific river systems (Sands et al. 2002). The Kvichak, Alagnak, and Naknek river systems are included within the Naknek-Kvichak District. This district is further divided into separate Kvichak and Naknek sections, and a Special Harvest Area in the lower section of the Naknek River (Figure 3). Distinct districts, sections, and special harvest areas allow managers to target fishing effort on specific fish stocks or groups of stocks, while protecting others.

Prior to commercial fishing, Native Alaskans harvested Bristol Bay salmon for subsistence uses. In recognition of the continued traditional, cultural, and economic importance of subsistence, providing opportunities for subsistence fishing is a greater regu-

latory priority than providing opportunities for both commercial and sport fishing. Annual subsistence harvest of Kvichak River sockeye salmon has averaged 69 thousand fish from 1981 to 2000 (Sands et al. 2002).

Annual Kvichak stock data collection

Kvichak River sockeye salmon data are collected annually for inseason management, spawning escapement goal evaluation and run forecasting. Each spring since 1975, after ice has stopped flowing from Iliamna Lake, the number of migrating smolt is estimated using hydroacoustics. In addition, age, length, and weight information is obtained from smolt sampled with fyke nets (Crawford 2001).

With the return of adult sockeye salmon each summer, towers from which observers visually count salmon are erected on both banks of the Kvichak River below the outlet of Iliamna Lake. Counting towers were first used to estimate salmon passage in many Bristol Bay river systems in 1955 (Anderson 2000). Counts are conducted for 10 minutes of each hour on both sides of the river throughout the day. These counts are multiplied by six to estimate total hourly sockeye salmon passage at the site, and hourly estimates are used to estimate daily and seasonal estimates of escapement. Sockeye salmon are captured using a beach seine, and sampled at the tower site to obtain information on age, sex, and length of the escapement.

Counting tower operations have also been conducted on Alagnak River (Morstad et al. 2004), a major tributary entering the Kvichak River below Iliamna Lake, as well as two systems above Iliamna Lake (personal communication, Carol Ann Woody, USGS): Newhalen River, the waterway connecting Lake Iliamna to Lake Clark, and Tazimina River, a tributary entering Six Mile Lake above Newhalen River. These operations have provided estimates of spawning sockeye salmon not included in the Kvichak River tower site estimate (Alagnak River), as well as information on the distribution of spawning sockeye above the Kvichak River tower site (Newhalen and Tazimina Rivers).

We regularly sample sockeye salmon delivered to commercial processing facilities to obtain age, sex, size and weight information for the component of the run harvested by the commercial fishery. These data are used to estimate the contribution of the Kvichak, Naknek, and Alagnak River runs to the catch using stock-specific differences in age composition and run timing patterns. Recently, work has also been done to develop genetic markers to identify individual stocks within stock mixtures (Habicht et al. In press; Olsen et al. 2003).

In the fall, spawning ground surveys are conducted to determine temporal and spatial distribution of spawning, the number of sockeye salmon below the tower site, and relative abundance of spawners (Morstad 2003). The University of Washington Fisheries Research Institute and ADF&G conduct these surveys each year. Surveys are accomplished either from an airplane or by walking the stream. In the past, surveys were sometimes done from boats. Recent surveys have not been as comprehensive as earlier ones due to budget reductions, and have primarily provided age and length data.

Each year, catch and escapement is estimated —in numbers of sockeye salmon by age—using data collected throughout the season. These data are appended to existing brood tables, which are used to determine spawning escapement goals and forecast future returns.

Kvichak spawning escapement goals

Since 1955, when counting towers first provided reliable estimates of spawning escapement, the number of Kvichak River spawners has ranged from 227 thousand to 24 million sockeye salmon. Escapement numbers achieved each year are largely dependent on run size and escapement goals. Escapement goals are designed to sustain salmon production and the fisheries dependent upon these runs. A BEG is a range of escapements that provides the greatest average annual yield from a stock and is the primary management objective.

The Bristol Bay region was one of the first areas in Alaska for which escapement goals were developed. BEGs for the Kvichak River were first established in 1962. These goals were expressed as point values until 1984 when BEGs were changed to ranges to allow for uncertainties associated with unpredictable and uncontrollable changes (often referred to as background variation or noise) as well as measurement and parameter errors.

Bristol Bay BEGs are reviewed on a schedule corresponding to the BOF triennial cycle for considering changes to area regulatory proposals. Reviews are a formal process involving a committee composed of staff from various organizations, including ADF&G, U.S. Fish and Wildlife Service, University of Alaska, and University of Washington. After the review committee reaches consensus, modified and new goals are presented to the public and the BOF for review and comments. Contrary to BEGs, optimum escapement goals are established by the BOF, and they incorporate biological, social, and economic factors.

Kvichak River BEGs are determined using two primary methods (Fair 2000). The first is a quantitative method based on fitting available data to stock-recruitment models (Ricker 1975). The second is a qualitative method based on an examination of available stock and recruitment data laid out in both graphic and tabular formats. The statistic of interest is surplus yield, the difference between observed recruitment and parental spawning escapement. Average surplus yields are calculated for different ranges of spawning escapement values to determine the spawning escapement range that has produced the greatest average surplus yield.

Goal History

The theories underlying Kvichak River sockeye salmon production, and, consequently, the goals themselves, have varied considerably over time (Table 1). From 1962 to 1984, management strategy was based on the hypothesis that abundance cycles were caused by a natural depensatory mechanism such as predation, and not by fishing. Therefore, goals were set based on the observed cycle of production (Figure 4):

- Small escapements of about 2 million spawners for off-cycle years.
- Intermediate escapements of about 6 million spawners for pre-peak years.
- Large escapements of about 14 million or more for peak years.

However, a very large off-cycle run in 1983 of 21 million sockeye salmon prompted reexamination of the cyclic dominance hypothesis. Studies by Rogers and Poe (1984) and Eggers and Rogers (1987) suggested cycles were caused by a combination of weather events, maintenance of small spawning escapements in off-cycle years by management practices, and brood year interactions. Eggers and Rogers (1987) further suggested that commercial fishing appeared to be the main depensatory factor responsible for cycles, since off-cycle runs were harvested at greater rates than either pre-peak or peak year runs.

Beginning in 1984, ADF&G adopted a management policy that attempted to moderate the cycle by implementing an escapement goal range of 4 to 10 million spawners. The lower end of the range was chosen because past spawning escapements less than 4 million sockeye salmon produced poorly, while escapements greater than 10 million sockeye salmon seemed to reduce production of the following brood year. Additionally, the goal for off-cycle years was set at 4 to 6 million sockeye salmon, while the goal for pre-peak and peak years was set at 6 to 10 million sockeye salmon. Since little data existed for spawning escapements between 4 and 10 million, this policy would also provide needed information on production from these levels of spawning escapement.

In 1998, ADF&G again modified the Kvichak River sockeye salmon escapement goal for a more robust variable escapement goal range based on actual run size and a conservative exploitation rate. For off-cycle years, the spawning escapement goal was expanded from a range of 4 to 6 million to 2 to10 million sockeye salmon. Support of the 2 million lower end

Table 1. Kvichak River sockeye salmon spawning escapement goals, actual escapements, and total runs from 1962 to 2003.

Year	Escapement Goal	Escapement	Total Run
1962	2.5	2.6	5.0
1963	0.8	0.3	0.7
1964	5.0	1.0	1.8
1965	8.0	24.3	47.7
1966	6.0	3.8	9.1
1967	3.5	3.2	5.6
1968	0.9	2.6	3.5
1969	6.0	8.4	13.5
1970	19.0	13.9	34.6
1971	2.5	2.4	6.9
1972	2.0	1.0	1.8
1973	2.0	0.2	0.3
1974	6.0	4.4	4.8
1975	14.0	13.1	15.4
1976	2.0	2.0	3.8
1977	2.0	1.3	2.3
1978	2.0	4.1	8.3
1979	6.0	11.2	25.3
1980	14.0	22.5	37.7
1981	2.0	1.8	7.5
1982	2.0	1.1	3.3
1983	2.0	3.6	21.0
1984	10.0	10.5	23.9
1985	10.0	7.2	14.1
1986	5.0	1.2	2.0
1987	5.0	6.1	9.8
1988	5.0	4.1	6.9
1989	8.0	8.3	20.5
1990	6.0	7.0	18.0
1991	4.0	4.2	8.3
1992	6.0	4.7	11.0
1993	5.0	4.0	9.9
1994	8.0	8.4	22.7
1995	10.0	10.0	28.3
1996	4.0	1.5	3.5
1997	4.0	1.5	1.8
1998	2.0	2.3	3.6
1999	6.0	6.2	13.3
2000	6.0	1.8	3.0
2001	2.0	1.1	1.4
2002	2.0	0.7	0.7
2003	2.0	1.7	1.8

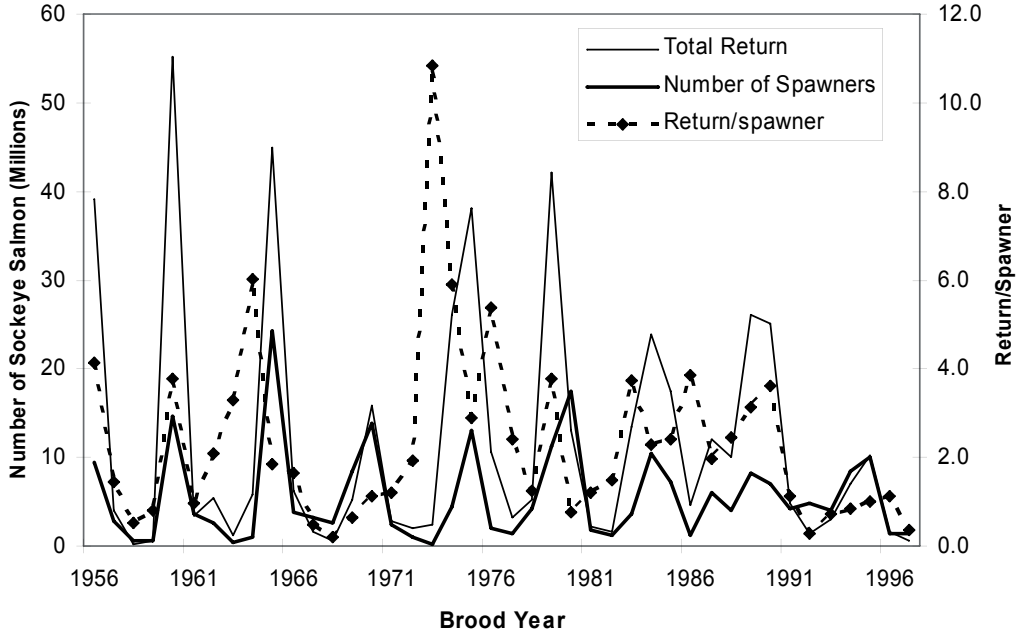

Figure 4. Number of spawners and total return of Kvichak River sockeye salmon by boood year.

of the off-cycle goal came from an MSY estimate of 2 million spawners and largest average surplus yields for spawning escapements less than 2 million. Pre-peak and peak goals remained at 6 to 10 million sockeye salmon. Additionally, an exploitation rate of 50% was established for runs of 4 to 20 million sockeye salmon. This provided guidance to managers on the desired spawning escapement level to obtain at various run sizes, and ensured that larger spawning escapements would be achieved from large off-cycle runs.

Management practices specific to the Kvichak

Many of the Bristol Bay salmon management practices discussed by Minard and Meacham (1987) are still followed today. This section discusses some of the more recent management actions that directly affect the Naknek-Kvichak District.

Management Plans

The Kvichak River is managed according to specific guidelines set forth in regulatory management plans (ADF&G 2001). These plans are developed through a public process, and the BOF takes and considers public testimony and local advisory group recommendations before deciding to reject, amend, or adopt regulatory proposals. Fishery management plans and regulations are in place for all of Bristol Bay, as well as for individual fishing districts. Bay-wide regulations direct ADF&G to achieve spawning escapement goals, maintain genetic diversity of stocks, and provide harvestable surplus to users. The commercial fishery is closed between June 1 and September 30, but it can be opened by Emergency Order.

There are two management plans addressing commercial fishing within the Naknek-Kvichak District. The first is referred to as the Commercial Set and Drift Gillnet Sockeye Salmon Fisheries Management and Allocation Plan (5AAC 06.364; ADF&G 2001). This plan specifies the allocation of sockeye salmon between commercial set and drift gillnet fisheries within the district and establishes management measures to achieve the allocation. Part of this plan (5AAC 06.364 (e); ADF&G, 2001) attempts to provide adequate Kvichak River sockeye salmon spawning escapement by managing, to the extent practicable, a fishery in the Naknek Section with limited set and drift gillnet gear fishing during ebb tides.

The second plan is referred to as the Naknek River Sockeye Salmon Special Harvest Area Management Plan (5AAC 06.360; ADF&G 2001). This plan states that on or after June 27, if Kvichak River cumulative escapement is one or more days behind the historical schedule for meeting the goal, the following actions are taken:

(a) The Naknek-Kvichak District will be closed, and to reduce the potential for interception of Kvichak River sockeye salmon in other districts,

(b) Fishing in the Egegik District may be restricted to the Egegik River Special Harvest Area,
(c) Fishing in the Ugashik District will occur within a restricted area prior to June 29, and
(d) If Naknek River spawning escapement is projected to be greater than 800,000 sockeye salmon, the Naknek River Special Harvest Area can open, and the upper spawning escapement goal for the Naknek River will be raised from 1.4 million to 2.0 million sockeye salmon.

These changes to the Bristol Bay fishery management plan have enabled the department to reduce fishing exploitation on Kvichak fish in the face of very weak runs. For example, in 2002 and 2003, the exploitation rate of Kvichak stocks has been between zero and two percent (Figure 5).

Inseason Run Strength Assessment

The Bristol Bay commercial fishery is managed using several measures of inseason run strength so that spawning escapement goals are met by distributing the escapement through time based on the historical run timing schedule. Commercial fishing periods are opened based on both spawning escapement and harvest indicators.

Because the primary management objective is to meet each system's spawning escapement goal, inseason assessment of escapement is critical for successful management. Daily and cumulative inseason escapement estimates, based on visual counts from towers, are compared to expected counts derived from historical averages of counts and run timing. This gives managers the ability to determine whether a run is smaller, the same, or larger than expected. Unfortunately, sockeye salmon often require several days to travel from fishing districts to the counting towers. This is because counting tower placement is based on water conditions such as depth, clarity, and velocity that tend to be best farther upstream near lake outlets. Therefore, inriver test fishing projects have been established to estimate the number of sockeye salmon that have left the fishing district but have not yet reached the counting tower (Crawford et al. 2002). This allows managers to provide adequate fishing opportunity to harvest surplus production while still achieving spawning escapement goals.

Commercial harvest information is used in a similar fashion to spawning escapement information. The actual daily and cumulative number of sockeye salmon harvested is compared to expected numbers derived from pre- and inseason projections to provide information on run size. Additionally, ADF&G conducts district test fishing during closed fishing periods to gauge the relative abundance and distribution of sockeye salmon within areas that may be open to harvest.

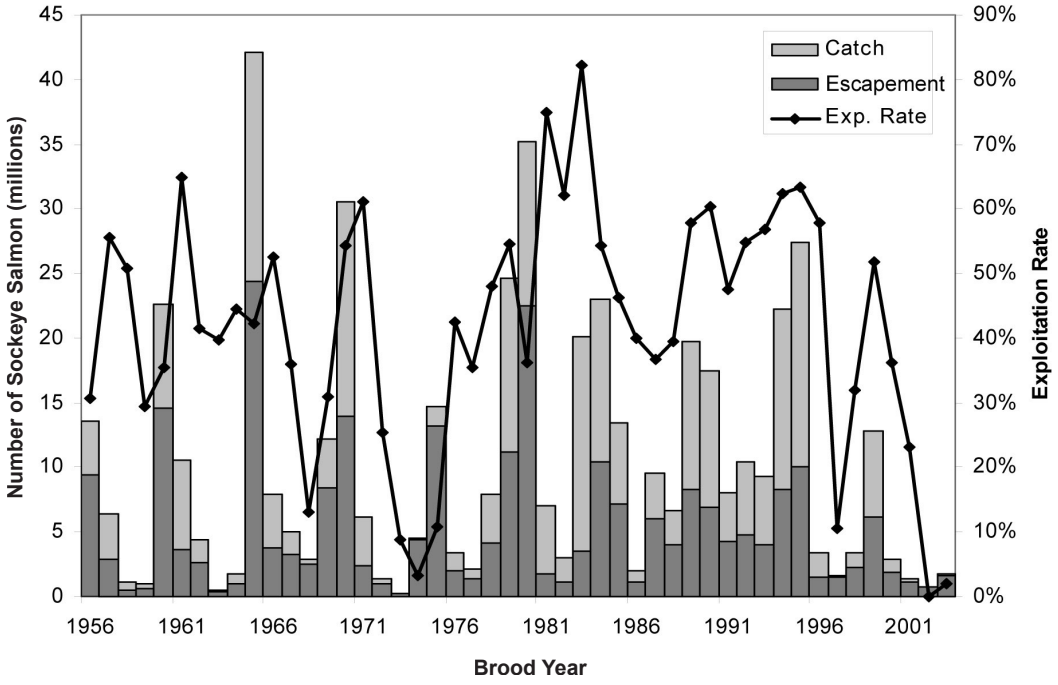

Figure 5. Kvichak river sockeye salmon catch, escapement, and exploitation rate from 1956 to 2003.

Commercial fishing in Bristol Bay is not opened by emergency order until indicators suggest a harvestable surplus of sockeye salmon is available. Openings are spaced throughout the entire run to ensure that sockeye salmon from all portions of the run are allowed to escape and spawn. Fishing periods are usually short in duration, and effects of the fishery are evaluated each tide. Also, when fishing is restricted to the Naknek Section of the Naknek-Kvichak District because the Kvichak River spawning escapement is below expectations, managers minimize ebb fishing since Kvichak sockeye salmon are more likely to be carried back with the receding tide into the harvest area.

FORECASTING AND PRODUCTION

Each fall, the following year's run is forecast using the most recent production data. Reliable predictions of future runs allow managers to (1) identify stocks which may need to be protected against over-harvesting, (2) estimate available commercial harvests, and (3) provide information to fishers and the seafood industry so that they can plan for the coming season. Kvichak River production has historically exhibited strong four- to five-year cycles which are poorly understood. As a result, forecasts of Kvichak River runs have historically performed more poorly than those made for other Bristol Bay systems. Another check on the forecasts was made using data from the smolt estimation program. From 1975 through 1992, the data provided a reasonable check on production of the Kvichak stock. However, since 1993, when the project was moved to a new site, the estimate has not been useful, and in fact, has likely misled ADF&G and others as to the status of the stock. Possible reasons might include the site change, a change in operating frequency of the sonar, and wind; however, to date, there is no resolution. We are currently evaluating a new sonar system that can monitor a larger proportion of the river flowing past the counting site and may provide more accurate estimates.

The Kvichak River system has the lowest sockeye salmon production (recruit-per-spawner) of any major system in Bristol Bay. Recent production (1991 to 1997 brood years) has been exceptionally poor, and spawning escapement goals have not been met in six of the last eight years (Figure 6). This is not unprecedented, and similar poor production has been documented for the 1965 to 1972 brood years. Both the Egegik and Ugashik river systems also experienced reduced production during these periods.

SYNOPSIS

To expedite rebuilding of the Kvichak River run, the BOF, with input from resource users and ADF&G, adopted additional management plans in the spring of

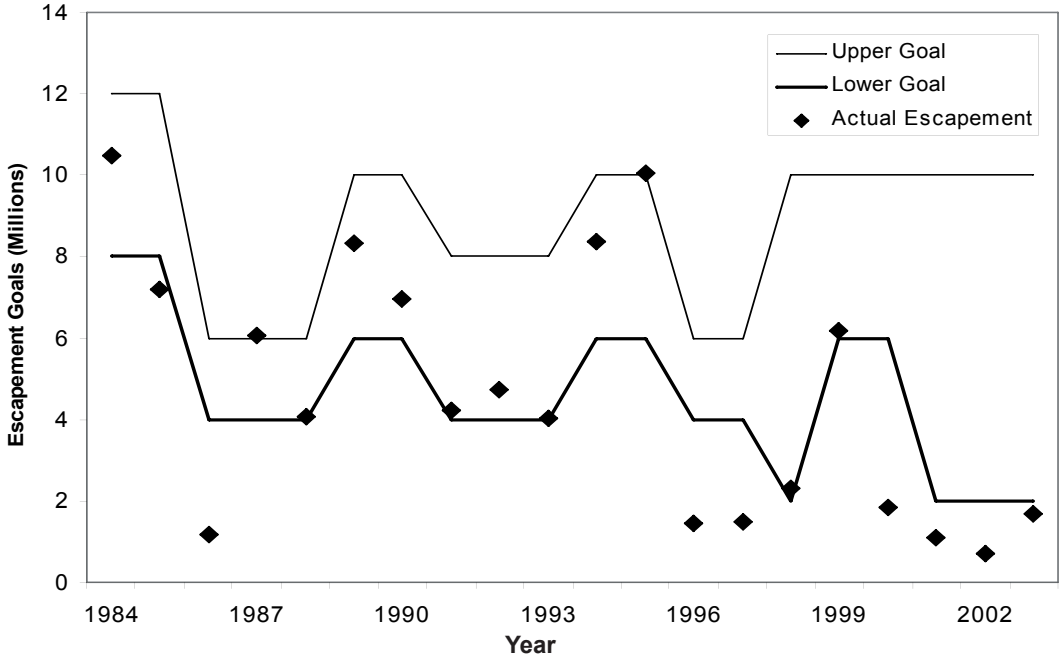

Figure 6. Kvichak River spawning escapement goal ranges and actual escapements from 1984 to 2003.

2001 to limit incidental harvest of Kvichak River sockeye salmon. While these restrictions were effective in reducing the harvest of Kvichak sockeye salmon, total escapement for this system still fell below the lower end of the spawning escapement goal range. Although these poor runs have restricted commercial and sport fisheries, we do not feel the sustainability of Kvichak River sockeye salmon is threatened at this time because the population has experienced previous eras of relatively poor production, such as that from 1971 to 1973, which was followed by high production and total returns. Additionally, previous spawning escapements below the 2000 to 2002 average of 1.2 million sockeye salmon had returns greater than replacement in 6 out of 8 instances. Kvichak River escapement goals are set for MSY; however, escapements below the established range can still be sustainable.

The Kvichak River watershed has remained relatively pristine and provides excellent spawning and rearing habitat for sockeye salmon. An existing Iliamna Lake limnology study is designed to better understand food and nutrient lake dynamics and improve our ability to estimate smolt abundance, which will help biologists better manage this resource.

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