THE SPRING CHINOOK PROGRAM AT QUILCENE NATIONAL FISH HATCHERY, 1981-1987, AND PROJECTIONS OF CATCH AND ESCAPEMENT TO THE YEAR 2010

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ABSTRACT

Puget Sound spring chinook have been reared at the U.S. Fish and Wildlife Service's Quilcene National Fish Hatchery since 1978. Brood stock came from Nooksack-Cowlitz crosses for the first three years of the program. Since 1984, we have had to rely solely on adults returning to the hatchery, even though we have not been able to reach our egg-take goal with these alone. Further stock transfers became impossible because of disease concerns at the Cowlitz Hatchery and lack of predictable surpluses from other Washington streams. This contributed to the inability to meet the Quilcene production goal of 400,000 yearling and 200,000 subyearling smolts. Another important factor was a disease outbreak at the hatchery. Disease has been well-controlled since 1985 through a variety of preventative measures, so that adult returns from the 1985 and 1986 broods are expected to progressively improve compared to previous years.

Poor adult returns were due primarily to low survival from release to adulthood, and secondarily to interception in the fisheries and possible poaching in the Big Quilcene River. The three most successful tag groups exhibited only 0.38% total survival to the hatchery and fishery. Increased emphasis on yearling smolt releases and other changes in release strategy should improve post-release survival beginning with the 1985 and 1986 broods. Yearling smolt releases also have apparently led to reduced interception in the Canadian fisheries. Interception in the Washington sport fishery seems to have been reduced in 1987 coincident with reduction in bag limit and extension of closed seasons and areas. More restrictions have recently gone into effect and are expected to further reduce the catch in subsequent years, and thus allow the brood run to build up. Effects of current rearing conditions and regulations will be best evaluated in 1990 after the four-year-olds from the 1986 brood have returned.

A predictive model of escapements and catches showed that increased post-release survival would greatly increase catch and escapement; reduced fishing effort gave moderate results. Supplementation with outside stocks would increase catch and hatchery returns but, unless survival of the imported stock were better than current Quilcene stock, supplementation alone would not result in a perpetuation of abundant brood stock. Specifically, a 100% increase in post-release survival would result in a self-sustaining brood run by 1992 and catches exceeding 20,000 by the year 2010. A 50% increase in survival coupled with supplementation of the Quilcene stock with 150,000 smolts annually for four years also provided a self-sustaining brood run by 1992 but allowed a catch of only about 6,000 by 2010. A 30% decrease in fishing effort alone resulted in sufficient brood stock by 1996 and produced a catch of 2,000 by 2010.

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INTRODUCTION

The protection and restoration of spring chinook runs has become an important state, tribal, and federal goal in western Washington. The U.S. Fish and Wildlife Service has been involved in these efforts since 1978. We have cooperated with the Washington Department of Fisheries (WDF) and the local tribes on the Nooksack, White, Dungeness, Queets, and Chehalis rivers in a variety of spring chinook projects. Our most concerted effort, however, has been to establish a broodstock at Quilcene National Fish Hatchery on northern Hood Canal (U.S. Fish and Wildlife Service 1980).

As stated in the Hood Canal Salmon Management Plan (WDF and Point No Point Treaty Council 1986), the spring chinook objective at Quilcene is production of smolts at a level providing enough adult returns to allow a surplus over hatchery broodstock requirements. This surplus would initially be stocked into the Skokomish River and other Hood Canal tributaries to rebuild natural stocks and provide recreational and commercial fishing opportunities. Stocking streams of Puget Sound and the Strait would also eventually be considered. At present, however, the Quilcene brood run has not been self-sustaining at the levels we had initially expected. Although the program was initiated 10 years ago, and between 120,000 and 450,000 smolts of imported stocks were released annually during the first brood cycle, hatchery escapements have been 200 or less, far below the goal of 500 adults. We believe the low escapement is primarily due to low marine survival, as will be described later.

The planned size of our program is set forth in the Hood Canal Salmon Management Plan, which is an agreement between WDF, the Point-No-Point Treaty Council, and the Service. Under this agreement the Hatchery is to release 400,000 spring chinook smolts at 20/lb. and 200,000 at 65/lb. each calendar year into the Big Quilcene River. To maintain these release numbers, a rack return of approximately 500 adults is required each year. Priority has been given to yearling (20/lb.) releases since these are thought to have the best survival to adults (Bill Hopley, WDF, pers. comm.).

Our policy since 1981 has been to use Puget Sound stock to the maximum extent possible. If a Puget Sound stock does not meet our egg requirement, we next consider stocks from coastal Washington, and finally from the Columbia River.

PROGRAM HISTORY

Our Quilcene spring chinook program began in the 1978 brood year using Hoodsport stock, which was a mixture of many local and non-local races. The influence of non-local stocks was thought to be a factor in poor survival of this stock at Quilcene. Therefore, we have been emphasizing local Puget Sound stock since the 1981 brood year. However, few stocks have been available to support the program. Each year, Service personnel have met with representatives of WDF and relevant tribes to assess the feasibility of transferring eggs from other sources including the Nooksack, Cowlitz, Soleduc, or Minter Creek programs. However, during the past four years we have been unable to secure outside brood stock.

In the 1981 through 1983 brood years we crossed Nooksack males with Cowlitz females since there were no purely Puget Sound stocks available (Table 1). Cowlitz eggs were readily available during the first three years of the program. We chose Nooksack over Skagit males, which may also have been available, because our involvement in cooperative, ongoing restoration on the South Fork Nooksack helped assure availability of Nooksack stock. The Nooksack stock used from 1981 through 1983 came almost entirely from brood stock collections by this office and the Lummi and Nooksack tribes on the South Fork and by WDF on the North Fork. We re-spawned these males after they had been first used by WDF or by the Lummi tribe.

We had hoped to continue infusing the Quilcene run with Puget Sound fish by annually crossing Nooksack spring-run males with females from the Quilcene returns or from Cowlitz stock. However, since the 1984 brood year neither Nooksack nor Cowlitz brood stock has been available. All available Nooksack spring-run stock has been set aside to rebuild the Nooksack brood runs, leaving only later-run fish for transfer to Quilcene in 1984 and 1986. These fish have recently been genetically characterized as fall-run, and measures are currently being taken to separate fall-run returns from our spring-run brood stock. The Cowlitz stock has been unavailable due to the risk of transmitting infectious hematopoietic necrosis from the Columbia River watershed. Instead, we have used only the Quilcene rack returns for brood since 1984.

A detailed account of Quilcene Hatchery spring chinook activities since 1983 is given in our annual hatchery reports (U.S. Fish and Wildlife Service 1985; Kenworthy 1986a,b; and Zajac 1988).

REASONS FOR LOW HATCHERY PRODUCTION

The production goal stated in the Hood Canal Salmon Management Plan has never been met (Table 2) because of either disease outbreaks at the hatchery or lack of brood stock. Although scarcity of egg sources is still affecting production, the disease problem has been alleviated, at least within the hatchery.

Brood Stock Shortages

Outside stocks as well as hatchery rack returns (Table 3) have been in short supply. This is in spite of our earlier expectation that rack returns would supply all our egg needs and eliminate the requirement for outside stock within a relatively short time. The 1987 escapement was surprisingly low despite unusually strong three-year-old returns in 1986. Possible explanations for brood stock shortages are discussed below.

Disease

Bacterial kidney disease (BKD) severely reduced the survival of smolts before their release in 1984 and probably reduced survival after release as well. A possible contributing factor was the unusual degree of handling due to construction at the hatchery. Disease has not greatly limited hatchery production since then. BKD is now controlled by separating eggs from infected brood stock, prophylactically injecting broodstock with erythromycin, reducing rearing densities, using a relatively hard freshwater source, adding some water from a saltwater well, feeding antibiotics, and minimizing handling. We are also conducting a cooperative study with the Olympia Fish Health Center to determine the relative performance of terramycin and galamycin in controlling BKD within the hatchery.

A further disease control effort was made beginning with the 1986 release, when the target release size was lowered from 15/lb. to 20/lb. This change seems to have improved the general health at release and consequently is also expected to reduce post-release mortality. However, smaller size at release is generally thought to decrease survival when disease control is not a factor. Therefore, the effectiveness of this measure will be evaluated by releasing marked smolts at several sizes, once production is increased enough to support such an experiment.

POSSIBLE REASONS FOR POOR ESCAPEMENT

Poor hatchery returns can be due to natural or fishing mortality or both. We reviewed causes of, controlling factors for, and management practices affecting natural marine mortality (Figure 1). Some marine mortality causes, such as weather and ocean conditions, are so far beyond human control that there is no hope of managing them. Other factors may be more manageable, however. As can be seen in Figure 1, there may be practical management alternatives at least partially addressing disease, predation, pollution, and habitat losses. Spring chinook management can generally benefit from increased applied research addressing any of the causes, controlling factors, or management practices. For example, Fish and Wildlife Service studies are underway to determine the effects of, and treatment for, bacterial kidney disease, thought to be a possible cause of losses of Quilcene spring chinook adults. Other ongoing research indicates adult spring chinook returning to the Big Quilcene River are being lost to harbor seals near the river mouth (Knudsen et al. 1989). Moreover, recent theoretical work has implied that the Nooksack X Cowlitz hybrids may not be the most genetically fit stock for use in the Quilcene program (John Emlin, National Fisheries Research Center, U.S. Fish and Wildlife Service, Seattle, pers. comm.). Poaching is also listed in Figure 1 under predation because poaching losses are essentially counted as marine mortality.

Survival

Data from tagging (Table 1) and recovery (Table 4) show poor survival between release and catch or escapement (Table 5) in comparison with other spring chinook programs in western Washington (Table 6). (Survival is here defined as the number of survivors from hatchery release to either the fishery or spawning escapement.) Water supply and disease problems at Quilcene Hatchery partially account for low survival of some Quilcene tag groups, but other Quilcene groups not obviously affected also survived poorly.

We suspect that BKD may be contributing to poor marine survival. For example, the 1982 brood experienced poor marine survival (Table 5) as well as serious losses to BKD before release from the hatchery. How BKD spreads in the population, or the degree of mortality caused by the disease after the fish are released from the hatchery, remains unresolved. Experiments are being conducted during summer, 1988 by the Service's National Fisheries Research Center in Seattle to better understand the spread of BKD in smolts held in seawater.

The three Quilcene yearling tag groups known to have not suffered extreme disease problems or to have had any other obvious rearing problems exhibited an average total survival to the fishery and escapement of 0.38%. This is somewhat below the median survival for other Puget Sound yearling spring chinook programs which ranged from 0.27 to 4.11% (Table 6). However, these comparisons should be viewed with caution because complete rearing history was not available for these stocks.

Subyearlings released in the spring from Quilcene did not survive as well as subyearlings released in the spring on the South Fork Nooksack (Tables 5 and 6). Even the one Quilcene subyearling group that was apparently healthy did not survive as well as the Nooksack group. Subyearlings released in the fall from Quilcene failed to survive to recapture. This group had to be released prematurely due to loss of hatchery water supply.

Marine survival estimates can be affected by predation, changes in fishing patterns, rearing practices, disease, genetics, or any combination of these factors. Some factors potentially affecting Quilcene spring chinook survival have been or are being investigated while others have not. Kenworthy et al. (1985) found that when releases were timed to reach the estuary at low tide in daylight, heavy predation by birds occurred. They recommended that releases be timed to reach the river mouth at high tide during the night and this practice, begun in 1986, continues.

In 1988 we conducted a study (Knudsen et al. 1989) to determine whether the abundant Quilcene Bay harbor seals were preying on smolts released from the hatchery. Our subjective interpretation of the observations was that seal predation on smolts was much less than bird predation, even after bird predation was reduced by timing releases as described above. During the study, however, we observed some seals preying on probable adult spring chinook; this could have dramatic effects on the population if many adults are being taken by seals.

The development of functional smolts is important to marine survival. Bills and Kenworthy (1986) performed preliminary seawater challenge tests and concluded that late May and early June were the optimum release times for Quilcene yearling smolts. Consequently, yearling smolts have been released in May since 1985.

Broods from 1984 and later are expected to survive better than prior years because rearing conditions have been improved. We released several replicate tag groups in the 1985 brood and tagged the majority of the 1986 and 1987 broods (Table 1) to enable evaluation of current hatchery practices as well as determine survival and contribution.

Yearling versus subyearling release

Quilcene smolts released as yearlings survived better than Quilcene smolts released as subyearlings (Table 5). Work by the Washington Department of Fisheries at other hatcheries has also generally indicated yearlings exhibit better marine survival than subyearlings (Paul Seidel, WDF, pers. comm.).

Tagged yearling releases contributed less to the Canadian catch, proportionally, than did tagged subyearling releases (Table 5). The Canadian share of the catch of yearling releases from Quilcene averaged 22.9% (Table 5), which falls roughly between the yearling contribution rates of the Skagit and Minter Creek programs (Table 6). Quilcene is farther from the Canadian fisheries than the Skagit River but, of course, closer than Minter Creek. The Canadian share of the catch of subyearling releases from Quilcene was similar to the share of subyearling releases from the South Fork Nooksack program (Table 6). These data support the theory that yearling releases tend to reside nearer their hatchery of origin, whereas subyearling releases tend to migrate further northward. Thus, yearling releases may be more amenable to conservation efforts than subyearling releases, to the degree that fishing restrictions can be negotiated more easily within the State than internationally.

WDF staff found that the relative proportion escaping to the hatchery is higher for subyearlings in some hatchery programs (Table 6). In contrast, Quilcene catch-to-escapement ratios were about equal for both yearling and subyearling releases (Table 5). These ratios were at the favorable end of the range compared to other programs (in terms of ensuring escapement past the fishery and into the hatchery). This, in addition to the low survival of subyearlings mentioned earlier, implies that no advantage will be gained at Quilcene by emphasizing subyearling release. After data from the 1988 run are available, a further assessment of the relative proportion escaping to the hatchery from subyearling and yearling releases will be possible.

Interception

Fishery interceptions also reduce adult returns to the hatchery (Figure 1). We examined contribution patterns of Quilcene spring chinook based on tag recoveries for the three most successful yearling tag groups (Table 5). On average, 50% of the total fishery interceptions were in Puget Sound sport catches, 39% in Canadian fisheries, and 11% were incidental catches in Puget Sound nets. Most of the Washington catch occurred in northern Puget Sound, and relatively few fish were caught on the Washington side of the Strait of Juan de Fuca (Table 7; Figure 2).

Within Puget Sound and the Washington side of the Strait, sport fisheries took a larger share of Quilcene spring chinook than the net fishery (Tables 4, 5 and 7). This also occurred in the Skagit and Minter Creek programs (Table 6). A sizable portion of the Quilcene spring chinook sport recoveries came from Hood Canal. The sport fishery caught Quilcene chinook throughout the year (Table 8). This further supports the hypothesis that most Quilcene yearling releases remain in Puget Sound where they can be caught at any time of the year.

Poaching

Poaching in the Big Quilcene River has probably contributed to low rack returns. The Quilcene run is particularly susceptible to poaching, because the 2.8 miles of river between the hatchery and saltwater are easily accessible, the holding pools are relatively shallow, and the water is very clear for most of the adult holding period. Poaching may explain some of the high variability in timing among the years as documented by our biweekly snorkel surveys, conducted each year since 1984. Examples are the apparent disappearance of adults from the river between Weeks 23 and 25 of 1984 and between Weeks 25 and 29 of 1985 (Table 9; Figure 3).

Failure of Adults to Enter the Hatchery

In 1984, 1986, and 1988, many adults in the river did not ascend the hatchery ladder by late July. We therefore netted brood stock from the river in 1984 and 1988. This approach undoubtedly stresses fish and is not very efficient, leaving many in the river where natural spawning probably contributes little to total production. Attracting a greater proportion of adults to the hatchery may be possible by imprinting juveniles to a characteristic odor artificially supplied during rearing. Great Lakes fishery managers routinely use this technique to attract chinook and steelhead to specific tributaries (Hasler and Scholz 1980). More recent applications in Alaska (Dudiak, in preparation) suggest potential for Quilcene as well.

ANALYSIS OF LIMITATIONS TO QUILCENE SPRING CHINOOK RESTORATION

We decided to further investigate potential causes for poor broodstock returns and possible management alternatives for dealing with, or compensating for, those low returns. To do this, we first outlined the causes and possible remedies for low survival (Figure 1) and then we developed a spreadsheet model to help us evaluate the relative benefits of various actions. Since all other Puget Sound spring chinook stocks continue to remain depressed (Puget Sound Treaty Indian Tribes et al. 1987) and are not responding rapidly to restoration measures, we believe the model generally applies to other Puget Sound stocks as well.

Model-Based Predictions

To investigate the relative efficacy of various management options, we designed a spreadsheet model for Quilcene Hatchery spring chinook. The model estimated catches, hatchery returns, and subsequent releases based on the average of the three best yearling-release survival estimates from coded wire tagging (Table 10).

The generalized model can best be expressed as:

$$F_i = \sum (HS_{ij} * REL_j * FR_{ij})$$

where F_i = the number of females returning in year i,
HS_{ij} = average survival to escapement in year i for j release years,
REL_j = release group size in year j, and
FR_{ij} = the female to male ratio in year i for release year j.

FR was 0.44 for age four, 0.76 for age five, and 0.0 for other ages, as observed from all returns at Quilcene Hatchery.

Actual release values were used through 1989. Subsequent releases were estimated by:

$$REL_j = F_{i-2} * 2{,}750$$

where F_{i-2} = the number of females which returned 2 years earlier.

The value of 2,750 smolts produced per returning female was the greatest value observed at Quilcene Hatchery. At the outset, we varied this production rate widely and found the model to not be overly sensitive to it.

Total catches were estimated by:

$$TC_i = \sum (FS_{ij} * REL_j)$$

where FS_{ij} = average survival to the fishery in year i for release year j.

Total hatchery returns were estimated by:

$$TR_i = \sum (HS_{ij} * REL_j).$$

We ran simulations and examined trends in hatchery returns and catches under a number of scenarios. We assumed (1) a constant relation between number of females and subsequent smolts, (2) survival rates are accurate and will remain constant, (3) any supplemental stocks will exhibit the same survival as the Quilcene stock, and (4) any fish not caught because of a reduction in fishing would survive to escape to the hatchery the same year.

No action. If no management changes are made and survival rates do not change, the Quilcene spring chinook may slowly decline between now and 2010 (Figure 4).

Continual supplementation with an additional 150,00 smolts from an outside source. This strategy would theoretically result in obtaining the hatchery escapement goal by 2004 (Figure 4). Catches would gradually increase to over 2,000 by 2010. Several supplementation values were tested in the model and 150,000 was found to be the smallest round number allowing attainment of the escapement goal before 2010. The major drawback to this alternative is that it depends on continual supplementation.

Supplementation for one brood cycle with 500,000 additional smolts. This alternative would initially reach the escapement goal by 1993 (Figure 4). However, if supplementation is not continued, the population begins to decline again at the same rate as with no action. Likewise, catches increase sharply but then decline.

Reductions in fishing mortality of 10, 20, or 30%. Reductions in fishing mortality of 10% results in only slow increase in the population; the escapement slowly increases but only reaches 299 by 2010. A 20% reduction, however, would result in meeting the escapement goal by 2003 with catches reaching 1,285 by 2010 (Figure 4). If fishing effort were reduced 30%, the escapement goal would be reached by 1996 and the catches would exceed 2,000 by 2010. This is a classic example of the Schaefer (1954) catch per effort model whereby a reduction in effort can result in increased catches.

Decrease fishing mortality 10% and supplement with 150,000 smolts for one brood cycle. This approach estimates that the escapement goal would be attained by 2003 and catches would exceed 1,300 annually by 2010 (Figure 4).

Reduction of fishing mortality by 10% with simultaneous increase in survival 10%. This would be relatively easy to manage for, and would possibly result in an escapement of 500 by 2009 and catches of 1,162 by 2010 (Figure 4).

Fifty percent increase in survival with 150,000 supplemental smolts for one brood cycle. Hatchery escapement would reach 500 by 1992 and catches would exceed 6,000 by 2010 (Figure 4).

Increase in marine survival of 50 or 100%. These alternatives might be effected by various measures such as disease control, reduction in predation during downstream and upstream migration, control of poaching, etc. If it were possible to increase survival by 50%, the model predicts the escapement goal would be met by 2000 and catches would exceed 3,500 by 2010 (Figure 4). If survival could be increased 100%, the escapement goal would be met by 1992 and catches would approach 20,000 by 2010. It is not unrealistic that survivals could be increased by 50 or 100% because these rates, and greater, have occurred in other Puget Sound spring chinook stocks (Table 6).

Discussion

There are several alternatives which, according to the model, will help to build the Quilcene spring chinook brood stock. Each of the several scenarios with potential to increase brood stock utilizes, to some degree, one or more of the management alternatives listed in Figure 1. It is clear that increasing marine survival would most expediently and dramatically increase returns to the hatchery and fishery. However, while some measures, such as reduction in poaching, may be relatively easy to implement, others, such as disease and predator control, will likely be more difficult. The Service is actively pursuing solutions to these problems but answers will probably be relatively slow in coming. Results from marine survival research will be gradually applied as management practices to improve survival are developed.

Reduced fishing combined with supplementation with outside stocks, or various combinations of reduced fishing, supplementation, and increased survival, can help in establishing a brood stock at Quilcene. As long as Hood Canal Salmon Management Plan cooperators remain committed to restoring spring chinook, management options, preferably the most effective ones, can and should be implemented whenever other resource considerations permit.

While management by fishing regulation is politically unattractive, temporarily protecting rebuilding stocks will buy time while research on marine survival is advanced. Current management may already provide protection and may only need refinement to more adequately protect weak spring chinook stocks while allowing healthy stocks to be harvested. First, Washington sport fishing regulations presently protect spring chinook with a maximum size limit in the Strait of Juan de Fuca. Tag recovery data presented in this report indicate a majority of the sport catch of fish released as yearlings occurs in Puget Sound and Hood Canal, rather than the Strait. If the maximum size limit were extended to other Puget Sound areas, more females may escape to all Puget Sound spring chinook rivers. Second, as described by Walters (1987), quota regulation under the Pacific Salmon Treaty will tend to protect weak stocks if enhancement increases total abundance in mixed-stock areas and quotas are not increased. The key to effectiveness of this strategy is the increase in abundance in the mixed-stock fishing areas.

A basic assumption of the models regarding supplementation was that imported stocks would exhibit survival rates similar to Quilcene spring chinook. It is not unreasonable to suspect that a properly chosen and managed introduced stock could have greater survival than the Quilcene stock. However, we will always be managing by crystal ball biology until some management-oriented research is conducted to determine whether the observed low marine survival at Quilcene is stock-based or a geographic problem. To investigate these questions, we propose that an outside stock be reared separately from Quilcene stock at Quilcene Hatchery simultaneously with separate rearing of Quilcene stock and the outside stock at Hood Canal Hatchery. All smolts would be coded-wire-tagged to study relative survival and escapement of the four test groups and to enable separation of the stocks for separate spawning at return. This experimental design would allow conclusions regarding differences in survival between different stocks and between different rearing locations. It may result in the abandonment of one stock, or location, in favor of the other, or in abandonment of spring chinook restoration in Hood Canal altogether. Experimental results would generally shed light on management alternatives for all Puget Sound stocks.

Importation of outside stocks for the experiment would also serve the basic function of supplementing the Quilcene stock while studies on improving marine survival are completed and their results implemented.

MANAGEMENT ISSUES

State and tribal fishery managers have made considerable sacrifices of fishing opportunity to protect Puget Sound spring chinook. Actual and potential management alternatives to allow more fish to escape to the hatchery are listed in Figure 1. Alternatives actually attempted in the mixed-stock sport fishery include a maximum size limit and restrictions in bag limit, fishing days, and seasons. Further protection of the Quilcene run has been attempted through sport and commercial closure of Quilcene Bay for chinook. The current emphasis on sport regulations seems well-directed since the Washington sport catch of Quilcene fish was about three times larger than the net catch (Table 4). The following observations may aid in evaluating and refining these measures.

Restrictions in Mixed-Stock Areas

Maximum size limit. The effectiveness of the 30-inch total length maximum size limit in reducing sport interceptions has been a concern since 1985. Its purpose was to protect 80% of the four-year-old spring chinook returning to Puget Sound (Kenworthy 1986a). This age was chosen because four- or five-year-olds include most of the females, upon which the egg take depends.

Prior to 1988, the 30-inch maximum size limit covered only Areas 5, 6, and 7 (Figure 2), and lasted from April 15 to June 15. These areas and times may have protected other important Puget Sound spring chinook runs, but did not coincide with the distribution and timing of the limited Quilcene tag recoveries available (Table 8). In 1988, WDF expanded the areas subject to maximum size limits to include areas 5 through 11, Area 12 south to a line from Quatsap Point to Misery Point (Figure 5), and all of Area 13. This more adequately covers the major catch areas for yearling-released fish from Quilcene.

Reductions in season and bag limits. Fisheries added certain restrictions to the sport fishery after the 1986 season. In the Strait and mid-Sound (Areas 5 through 9 in Figure 2), the bag limit was reduced from three salmon, only two of which could be chinook, to a total of two salmon of any species. These changes coincided in 1987 with a higher proportion of Quilcene fish reaching the hatchery compared to the number entering the sport catch than was seen in previous years (Table 11). Analysis of data from several more years of tag recovery will be necessary to definitively conclude whether sport fishing regulations have been effective in protecting Quilcene spring chinook.

Closure of Terminal Area

The terminal area of Quilcene Bay west of Point Whitney (Figure 5) was closed from April 1 to June 30 in 1985-1987 to limit sport interception in that area. Most Hood Canal (Area 12) sport catch was landed close to Quilcene Bay. Specifically, the landings were reported at Jackson Cove, Oak Head, Hazel Point, Seabeck Bay, and Misery Point (Dick O'Connor, WDF, pers. comm.). These considerations led to expansion of the terminal area closure in the 1988 sport regulations to include Dabob Bay north of Pulali Point. However, a substantial part of the tags were recovered during the late summer or during the winter when the closure was not in effect. More sport catch data on actual landing points would help evaluate the real effect of this restriction.

Terminal area closure seemed better justified from the standpoint of timing in the Big Quilcene River. The April 1 (Week 14) closure would protect early-returning individuals if they do not mill very long in Quilcene Bay before entering the river. Less than ten percent of the run can be expected in the river before mid-April, or Week 16 (Figure 3). The June 30 (Week 27) opening of Quilcene Bay, however, cannot be expected to completely protect late-returning individuals. For example, in 1986 only about 50% of the run had entered the river by week of June 29 - July 5. In other years the problem was not so severe, and percentages of the run in the river on or before Week 27 ranged from 75% in 1984 to 100% in 1985. As a result, the closed season in this area now lasts through August 15.

The Service has also requested the Washington Department of Wildlife to close the Big Quilcene River steelhead season at the end of February instead of the end of March. This would possibly reduce the suspected incidental catch of early-returning adults.

SUMMARY AND CONCLUSIONS

1. The Service goal is to develop a spring chinook brood stock that can be used within appropriate streams of Hood Canal, the Strait, and Puget Sound to establish self-sustaining populations and eventually provide harvestable numbers.

2. Scarcity of egg sources is reducing development of the brood stock. Production has depended on local brood since 1984, but this has never provided more than half our egg requirement.

3. Disease problems have arisen but are now being better controlled.

   a. Bacterial kidney disease severely reduced smolt survival before release in 1984, but since 1985 the disease problem has been greatly alleviated by preventative measures.

   b. A further disease control effort began with the 1984 brood, when the target release size was lowered from 15/lb. to 20/lb.

4. We expect progressively better post-release survival from the 1985 and 1986 broods because of yearling releases and improvements in disease management and rearing conditions.

   a. Releases since 1985 have been timed to reach the river mouth at night during high tide to reduce predation by birds.

   b. Since a reduction in fishery interception by releasing smolts as subyearlings offers no advantage at Quilcene, all releases have been made as yearlings since the 1984 brood.

   c. Since yearling releases contributed less to the Canadian catch, proportionally, than did subyearling releases, yearling releases are more amenable to Washington state's protection efforts.

   d. Since the majority of the run returns at age-4, we will have good data for evaluation of these practices by 1990 and definitive evaluation of the Quilcene program prior to 1990 may be premature.

5. The Washington sport fishery harvests about 50%, Canadian fisheries harvest about 39%, and Washington commercial harvests about 11% of the total catch of yearling releases.

6. Fishery management practices are basically sound but some refinement is desirable.

   a. Tag returns imply that poor adult returns are due primarily to poor survival from smolt to adult. In contrast, fishery interception was fairly low relative to other Puget Sound spring chinook runs, and is expected to decrease in the coming years due to additional fishery restrictions.

   b. Most Washington catches occurred in northern Puget Sound and northern Hood Canal; relatively few fish were caught in the Strait. The existing focus of some regulations on the Strait is not very relevant to protection of the Quilcene stock.

   c. The Washington sport catch of Quilcene fish was about three times larger than the net catch. The current emphasis on sport regulations seems well-directed.

   d. The sport fishery caught Quilcene chinook throughout the year, although existing regulations seem to presuppose a strong seasonal migration.

   e. Washington Department of Fisheries lowered the bag limits in northern Puget Sound sport fishery after the 1986 season. These changes coincided with a higher proportion of Quilcene fish reaching the hatchery compared to the number of Quilcene fish entering the sport catch in 1987, than was seen in previous years.

   f. The current closure of Quilcene Bay and northern Dabob Bay from April 15 to August 15 should be effective in protecting Quilcene spring chinook once they enter those areas, in view of their entry timing into the Big Quilcene River.

g. Poaching in the Big Quilcene River is probably contributing to poor adult returns at the hatchery.

7. The Quilcene spring chinook stock will probably gradually decline unless some new management options are exercised. A predictive model of escapements and catches suggested supplementation with outside stocks would not alone result in rapid development of a brood stock. However, increased post-release survival, reductions in fishing effort, and, to a lesser extent, supplementation with outside stocks would greatly increase catch and escapement.

RECOMMENDATIONS

1. We recommend that supplementation of the Quilcene stock be conducted experimentally so survival can be compared between spring chinook of different stocks reared at different locations.

2. Hood Canal hatchery should be brought into spring chinook production, using stock from both Quilcene and some other appropriate source.

3. Consideration should be given to an earlier closure of area 12A to chinook fishing to further protect spring chinook returning to Quilcene.

4. Chemical imprinting should be investigated as a means of attracting a greater proportion of river-returning adults to the hatchery rack.

5. Evaluate the relative merits of releasing smolts early to avoid disease incidence versus releasing later to achieve better survival.

6. Further studies should be performed to determine the effect adult harbor seals are having on the number of adults escaping to the hatchery.

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Table 1. Releases of spring chinook by brood year and tag groups. Brood year 87 fish are still in the hatchery.

Brood year	Release date	Total release	Size (No./lb.)	Stock	Tag code	Percent tagged
81	10/82	152,245	17.3	North Fork Nooksack X Cowlitz	5-10-17	17.9
	5/83	155,051	11.9	South Fork Nooksack X Cowlitz	5-10-33	18.3
82	6/83	51,928	92.1	South Fork Nooksack X Cowlitz	5-14-19	89.6
	3/84	109,764	9.6	North Fork Nooksack X Cowlitz	5-13-47	17.3
		217,833	12.5	South Fork Nooksack X Cowlitz	5-13-48	11.4
83	6/84	150,392	67.0	North Fork Nooksack X Cowlitz	5-14-54	31.8
		51,560	69.0	South Fork Nooksack X Cowlitz	5-14-26	91.2
	5/85	55,289	10.2	North Fork Nooksack X Cowlitz	5-14-52	48.8
		401,730	17.2	South Fork Nooksack X Cowlitz	5-14-53	6.4
84	5/86	27,695	24.2	Quilcene	none	0.0
85	5/87	28,082	23.0	Quilcene	5-8-32	90.6
		29,620	23.0	Quilcene	5-14-62	93.2
		25,391	23.0	Quilcene	5-17-48	85.9
		24,374	23.0	Quilcene	5-17-49	84.9
		24,141	23.0	Quilcene	5-17-50	77.2
		25,875	23.0	Quilcene	5-18-31	88.7
		26,124	23.0	Quilcene	5-18-32	85.7
		26,098	23.0	Quilcene	5-18-33	87.1
		5,879	23.0	Quilcene	none	0.0
86	5/88	133,456	20.2	Quilcene	5-19-11	96.1
		3,140	17.8	Quilcene	none	0.0

Table 2. Annual releases of spring chinook into the Big Quilcene River from Quilcene National Fish Hatchery.

Release year	Yearlings (Goal = 400,000)	Subyearlings (Goal = 200,000)
82	152,245	0
83	155,051	51,928
84	327,597	201,952
85	457,019	0
86	27,695	0
87	215,584	0
88	136,596	0

Table 3. Spring chinook returns to Quilcene, 1983-87, by age and sex.

Return year	Age	Brood year	Male	Female	Total
83	2	81	26	0	26
	3	80	0	1	1
	Total		26	1	27
84	3	81	19	1	20
	4	80	20	14	34
	Total		39	15	54
85	3	82	5	0	5
	4	81	61	68	129
	5	80	2	13	15
	Total		68	84(a)	152(a)
86	2	84	7(b)	0	7(b)
	3	83	113	0	113
	4	82	15	1	16
	5	81	16	52	68
	Total		151(b)	53	204(b)
87	3	84	8	0	8
	4	83	52	32	84
	5	82	6	10	16
	6	81	1	0	1
	Total		67	42	109

(a) Including three fish of undetermined age.

(b) Total rack return for two-year-olds was 48, but included progeny of fall-run fish inadvertently released into the Quilcene from the 1984 brood year. The spring-run component of 7 fish was estimated by multiplying total rack return of 48 by the percentage of spring-run fish released from the 1984 brood year. Releases originating from that year were 27,695 springs and 176,660 falls. In the 1987 return year, late-returning fish were not reported as spring-run rack return.

Table 4. Expanded tag recoveries from Washington and British Columbia, calculated by dividing the observed recoveries (shown here in parentheses) by the mark sampling rate. Data for 1986 and 1987 are preliminary. Last revised Feb. 19, 1988 from Pacific Marine Fisheries Commission data.

Brood year	Tag code	Recovery year	Rack return	Puget Sound Coml. (a)	Puget Sound Sport	British Columbia, Vancouver Island, East Coast Net	British Columbia, Vancouver Island, East Coast Sport	British Columbia, Vancouver Island, West Coast(b) Coml.	British Columbia, Vancouver Island, West Coast(b) Sport	British Columbia, North & Central Coml.
81	5-10-17 (c)	83-87	0	0	0	0	0	0	0	0
	5-10-33	83	6(6)	10(2)	0	0	0	0	0	0
		84	2(2)	5(3)	7(2)	4(1)	17(4)	0	0	0
		85	19(19)	2(1)	44(9)	0	0	37(8)	6(1)	0
		86	9(9)	0	1(1)	0	0	0	0	0
		87	1(1)	0	0	0	0	0	0	0
82	5-13-47 (d)	85-87	0	0	0	0	0	0	0	0
	5-13-48	85	0	10(1)	0	0	0	0	0	0
	(d)	86	0	0	0	0	0	0	0	0
		87	1(1)	0	1(1)	0	0	0	0	0
	5-14-19	85	1(1)	5(2)	5(1)	0	0	6(2)	2(1)	0
		86	4(4)	0	3(1)	0	0	10(2)	0	0
		87	5(5)	0	0	0	0	0	0	0
83	5-14-26 (d)	86	2(2)	0	0	0	0	3(1)	0	0
	5-14-52	86	2(2)	4(2)	37(6)	0	5(1)	0	0	3(1)
		87	10(10)	6(1)(e)	4(1)	0	7(1)	3(1)	0	7(2)
	5-14-53	86	7(7)	0	22(4)	0	0	0	0	0
		87	2(2)	0	3(1)	0	0	3(1)(f)	0	0
	5-14-54	86	3(3)	0	8(1)	0	5(1)	10(2)	0	0
	(d)	87	3(3)	0	0	0	0	0	0	0
	Total		77(77)	42(11)	135(28)	4(1)	34(7)	72(17)	8(2)	10(3)

(a) Includes American side of Strait of Juan de Fuca.
(b) Includes Canadian side of Strait of Juan de Fuca.
(c) Released prematurely due to water supply problem.
(d) Post-release survival probably affected by disease.
(e) From Area 6C Indian troll fishery. No other Quilcene spring chinook tags have been reported from this fishery.
(f) Recoveries for Area 20 net fishery. No other Quilcene spring chinook tags have been reported from this area.

Table 5. Survival, contribution, and catch-to-escapement ratio for Quilcene spring chinook based on tag recoveries from 1973 through 1978.

Brood year	Tag code	Tags Released	Total Survival	Rack (b)	Expanded recoveries(a) Washington Sport	Washington Coml.	British Columbia	Total	Catch/ Escapement
				Released as Yearlings in the Spring (10-17/lb.)					
81	5-10-33	28,442	0.60%	37	52	17	64	170	3.6
82	5-13-47	18,972	0.00%(c)	0	0	0	0	0	--
	5-13-48	24,820	0.05%(c)	1	1	10	0	12	11.0
83	5-14-52	26,974	0.33%	12	41	10	25	88	6.3
	5-14-53	25,737	0.14%	9	25	0	3	37	3.1
Mean percentage (d)					47.9	29.2	22.9		
				Released as Subyearlings in the Spring (67-92/lb.)					
82	5-14-19	46,505	0.09%	10	8	5	18	44	3.1
83	5-14-26	47,023	0.01%(c)	2	0	0	3	5	1.5
	5-14-54	47,880	0.06%(c)	6	8	0	15	29	3.8
Mean percentage(d)					20.2	5.4	74.4		
				Released as Subyearlings in the Fall (17/lb.)					
81	5-10-17	27,286	0.00%(e)	0	0	0	0	0	--

(a) Calculated as (tags observed)/(mark sampling rate). This does not account for unmarked members of the release group.
(b) No expansion needed because 100% of returns were mark sampled.
(c) Disease may have reduced post-release survival.
(d) Calculated as the unweighted mean of the percent distributions of the individual tag groups.
(e) Released prematurely due to water supply problem.

Table 6. Survival, percent contribution to fisheries, and catch-to-escapement ratio for comparable spring chinook runs in western Washington. (Sources: Paul Seidel, Salmon Culture Division, Washington Department of Fisheries, unpublished data, pers. comm., 1988; except for Skookum hatchery data, which was provided by Pete Castle, Washington Department of Fisheries, Mount Vernon, unpublished data.)

Hatchery	Stock	Brood year	Tag code	Total Survival	Percent of Catch(a) Puget Sound Sport	Puget Sound Coml.	British Columbia	Catch/ escapement
				Released as Yearlings in Spring (5-16/lb.)				
Kendall Creek	North Fork Nooksack	82	632546	0.27(b)	0.0	0.0	99.9	(d)
Skookum Creek	South Fork Nooksack	81	050634	2.66(b)	1.7	13.4	82.5	24.4
			050946	2.43(b)	0.3	11.9	86.9	28.0
		82	051418	2.11(c)	4.6	5.2	90.0	4.3
Skagit River	Skagit	81	632606	1.30	5.6	9.7	58.9	(d)
		82	632607	0.38	17.9	3.6	77.2	(d)
		83	632608	0.18	37.5	14.1	48.4	(d)
Minter Creek	White River	80	632136	1.32	45.0	10.5	2.8	2.2
		81	632604	0.09	62.9	0.0	0.0	2.3
		82	632853	4.11	55.0	18.9	2.8	(d)
		83	633049	3.13	73.8	13.4	12.8	(d)
				Released as Subyearlings in Spring (64/lb.)				
Skookum Creek	South Fork Nooksack	80	050837	0.66(b)	9.6	15.1	75.3	7.2
				Released as Subyearlings in Fall (9/lb.)				
Skookum Creek	South Fork Nooksack	80	050838	0.94(b)	13.2	26.0	59.9	11.4

(a) Total may not equal 100% because Alaska and coastal Washington catches are not shown here.
(b) Available data do not specify whether wild spawning is included in escapement and survival estimate.
(c) Wild spawning not included in survival estimate.
(d) Not available; release presumably was made off-station.

Table 7. Distribution of expanded coded wire tag catches from Washington, combining return years 1983-1987.

Area	Description	Expanded recoveries Coml.	Sport	Total
5	Clallam Bay and Sekiu	5	5	10
6	Port Angeles	8	14	22
	Strait subtotal	13	19	32
7	San Juan Islands	4	10	14
8	Saratoga Passage	14	13	27
9	Admiralty Inlet	0	29	29
10	Seattle	8	30	38
11	Tacoma	0	4	4
	Puget Sound subtotal	26	86	112
12	Hood Canal	3	30	33
	Washington total	42	135	177

Table 8. Distribution and timing of 1983-1987 expanded tag recoveries of Quilcene spring chinook in the sport catch. (Distribution is partially affected by closures and limits which vary with year, month, and area.)

Area	Jan	Feb	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
5			(a)	(a)		5						5
6					8			6				14
7								6			4	10
8									13			13
9		5	2	5(b)				5	4	4	4	29
10	5	5									20	30
11					4							4
12	12		4(c)	5(c)	(c)		3	3			3	30
Total	17	10	6	10	12	5	3	20	17	4	31	135

Table 9. Timing pattern of chinook in Big Quilcene River, as observed by snorkel survey, and approximate total in Quilcene National Fish Hatchery.

Week (a)	1984		1985		1986		1987	
	River	Hatchery	River	Hatchery	River	Hatchery	River	Hatchery
16			10	0				
18	5	0	24	1	22	2	13	1
20			36	4			33	0
21	11	1						
22					23	5	62	8
23			99	34	56	14		
24							59	24
25	38	5	133	56				
26					68	28	25	55
27	20	5	87	89				
28	44	5			71	89	30	84
29			56	101				
30	47	9	17	149	63	117		
31	41	15					25	98
32			8	154	47	156	18(b)	103(c)
33							11(b)	112(c)
34							12	100
35			14	154				
36		54		152		206		109

(a) Typical designation of statistical weeks is:

16	April 13-19	27	June 29-July 5
17	April 20-26	28	July 6-12
18	April 27-May 3	29	July 13-19
19	May 4-10	30	July 20-26
20	May 11-17	31	July 27-August 2
21	May 18-24	32	August 3-9
22	May 25-31	33	August 10-16
23	June 1-7	34	August 17-23
24	June 8-14	35	August 24-30
25	June 15-21	36	August 31-September 6
26	June 22-28		

(b) Based on expanded index counts of total salmon and approximate chinook/coho composition of run.

(c) Based on counts of total salmon and approximate chinook/coho composition of new arrivals in hatchery.

Table 10. Average fishery, hatchery, and total survival for Quilcene spring chinook.

	Percent survival		
Age	Fishery	Hatchery	Total
2	0.012	0.007	0.019
3	0.128	0.020	0.148
4	0.150	0.038	0.188
5	0.002	0.022	0.024
Total	0.292	0.087	0.379

Table 11. Estimated total contribution (expanded recoveries divided by fraction of group tagged) to Puget Sound sport fishery compared to adults returning to hatchery.

Recovery year	Rack return	Puget Sound sport recovery	
		Tagged	Total
83	27	0	0
84	54	7	38
85	152	49	246
86	204	71	453
87	109	8	64

SPRING CHINOOK MORTALITY

ACTUAL CAUSES	CONTROLLING FACTORS	MANAGEMENT PRACTICES
NATURAL MORTALITY		
Disease Predation Poaching Pollution Habitat losses Environmental stresses	Genetics Growth rate Hatchery practices Weather and ocean conditions Poaching pressure	Better broodstock Improved genetic fitness Disease control Improved hatchery practices Release strategies Increased law enforcement Predator control
FISHING MORTALITY		
British Columbia Washington sport commercial	Fishing effort Regulations	Gear regulations Size regulations Area closures Season closures

Figure 1. A listing of causes, controlling factors, and management practices regarding spring chinook natural and fishing mortality (the columns are independent; do not read across lines).

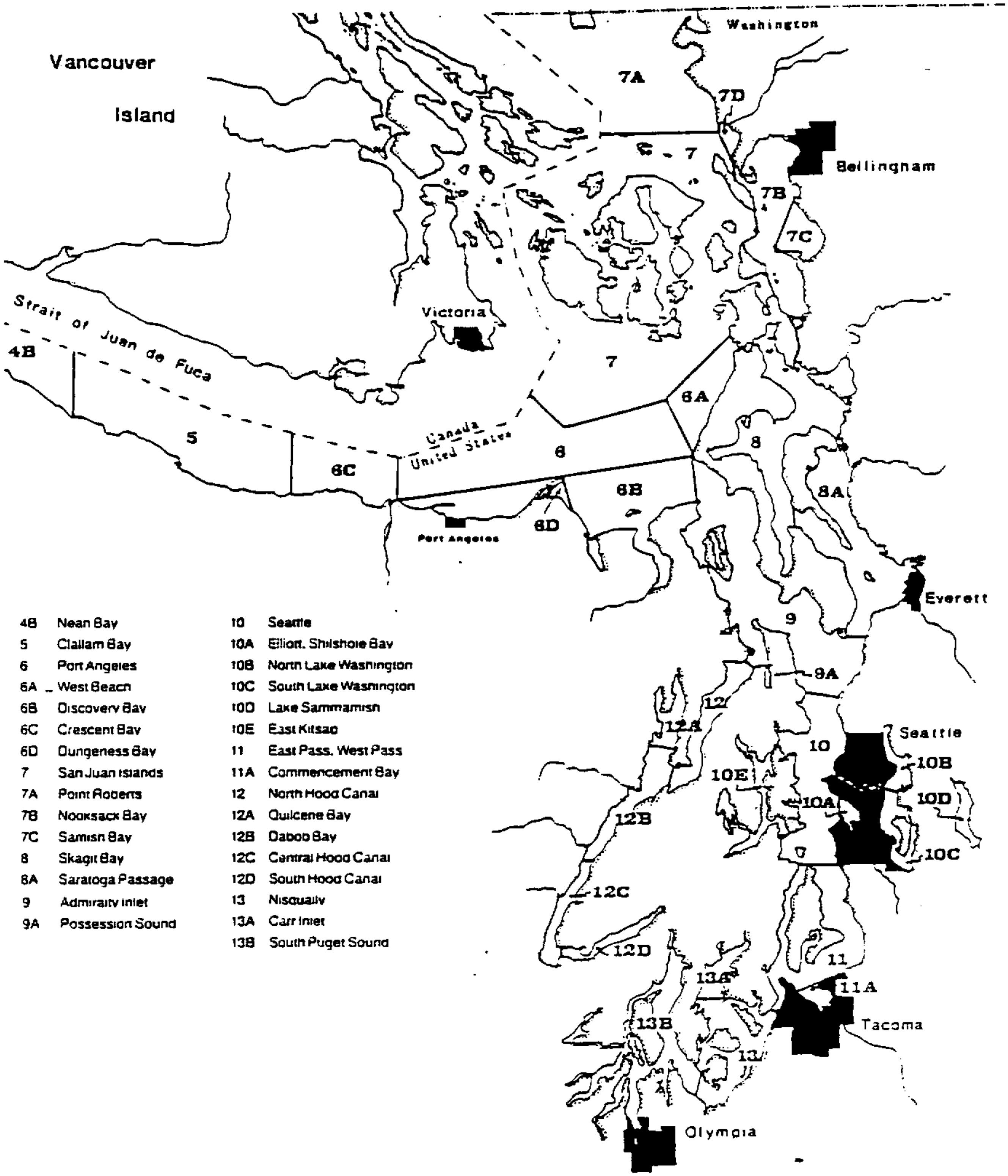

Figure 2. Map of the Puget Sound area showing Washington sport fishing areas. Note: lettered subdivisions of numbered areas do not apply to sport fishing regulations.

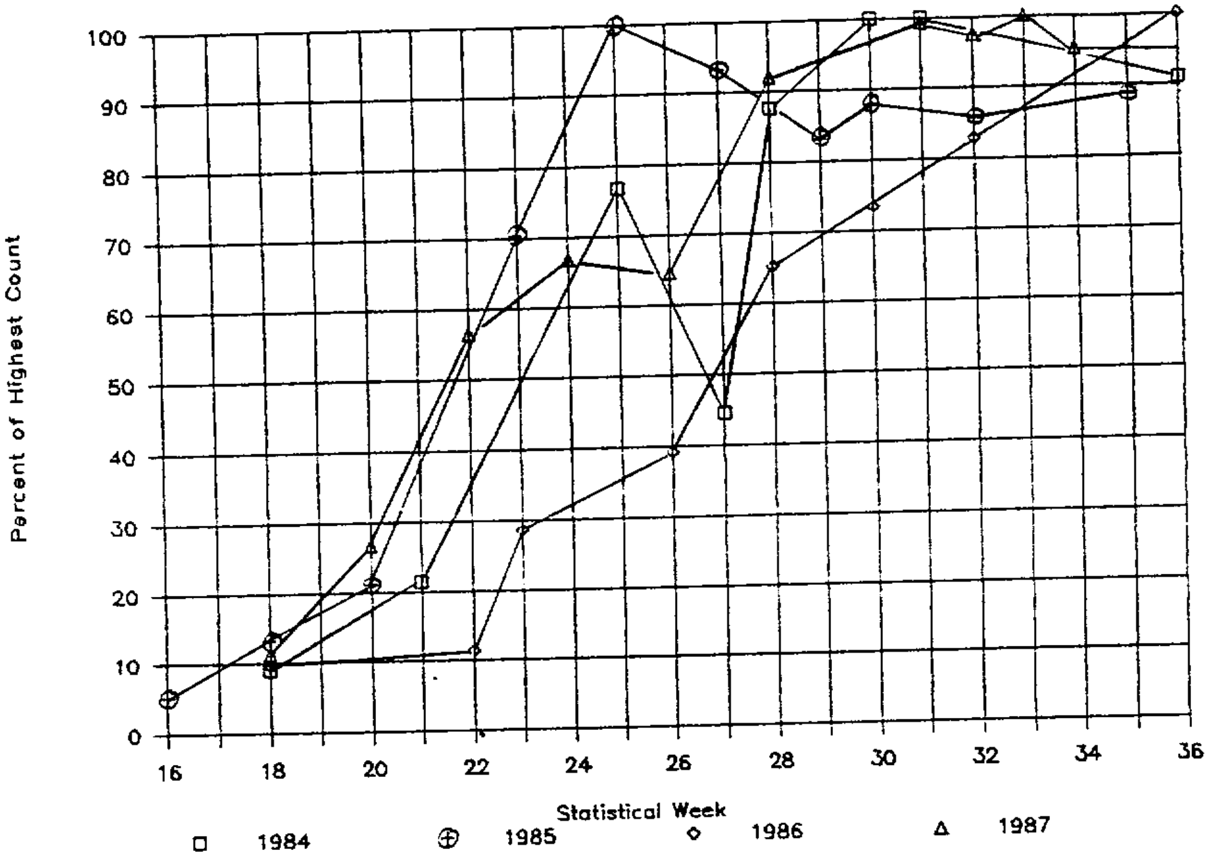

Figure 3. Timing of spring chinook: number observed in the Big Quilcene River, Miles 0.6-2.8, plus number estimated to have entered the Quilcene National Fish Hatchery. Typical designation of statistical weeks is:

16	April 13-19	27	June 29-July 5
17	April 20-26	28	July 6-12
18	April 27-May 3	29	July 13-19
19	May 4-10	30	July 20-26
20	May 11-17	31	July 27-August 2
21	May 18-24	32	August 3-9
22	May 25-31	33	August 10-16
23	June 1-7	34	August 17-23
24	June 8-14	35	August 24-30
25	June 15-21	36	August 31-September 6
26	June 22-28		

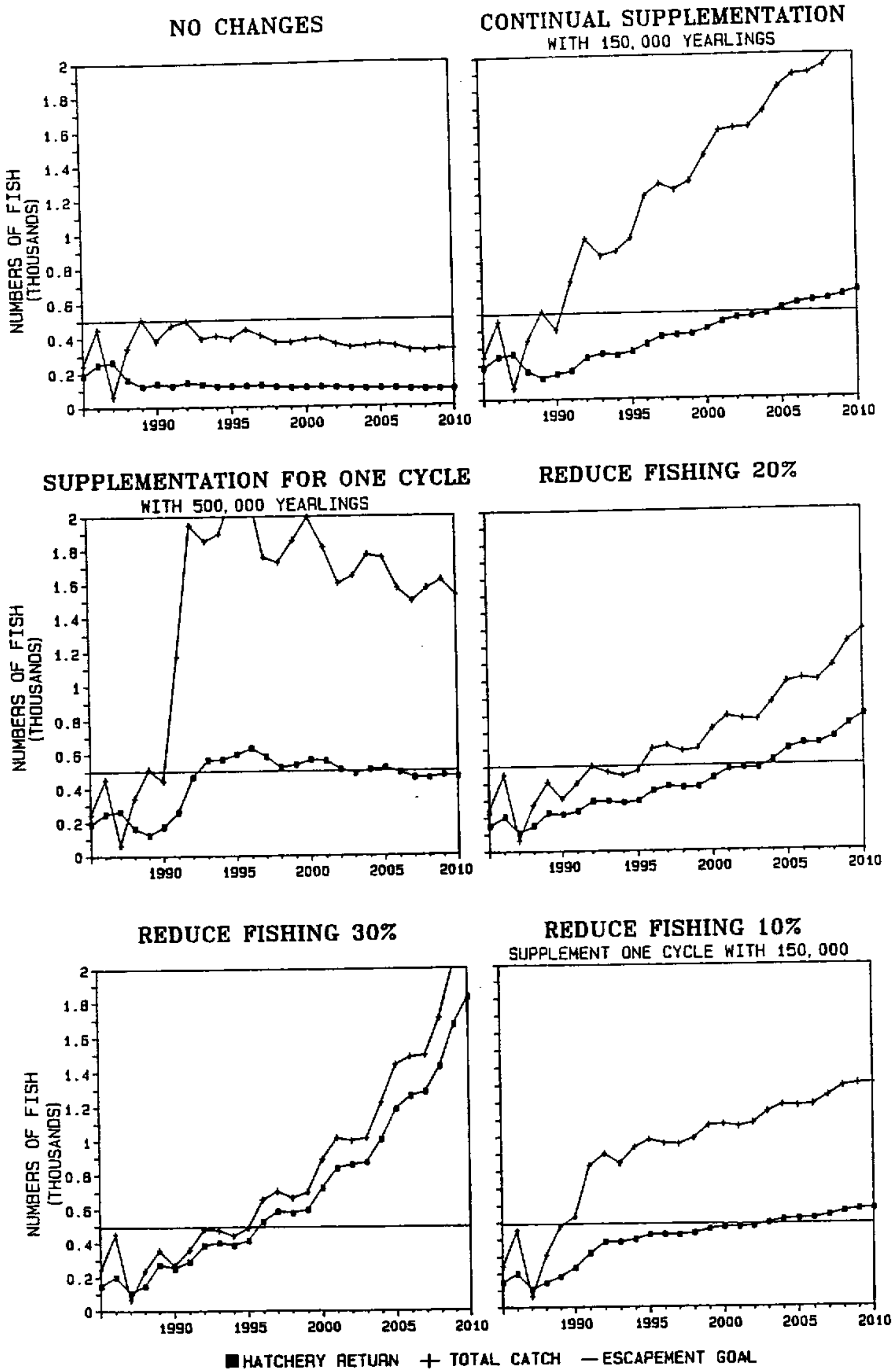

Figure 4. Projected hatchery returns and total catches of Quilcene spring chinook under various supplementation, fishery management, and survival scenarios.

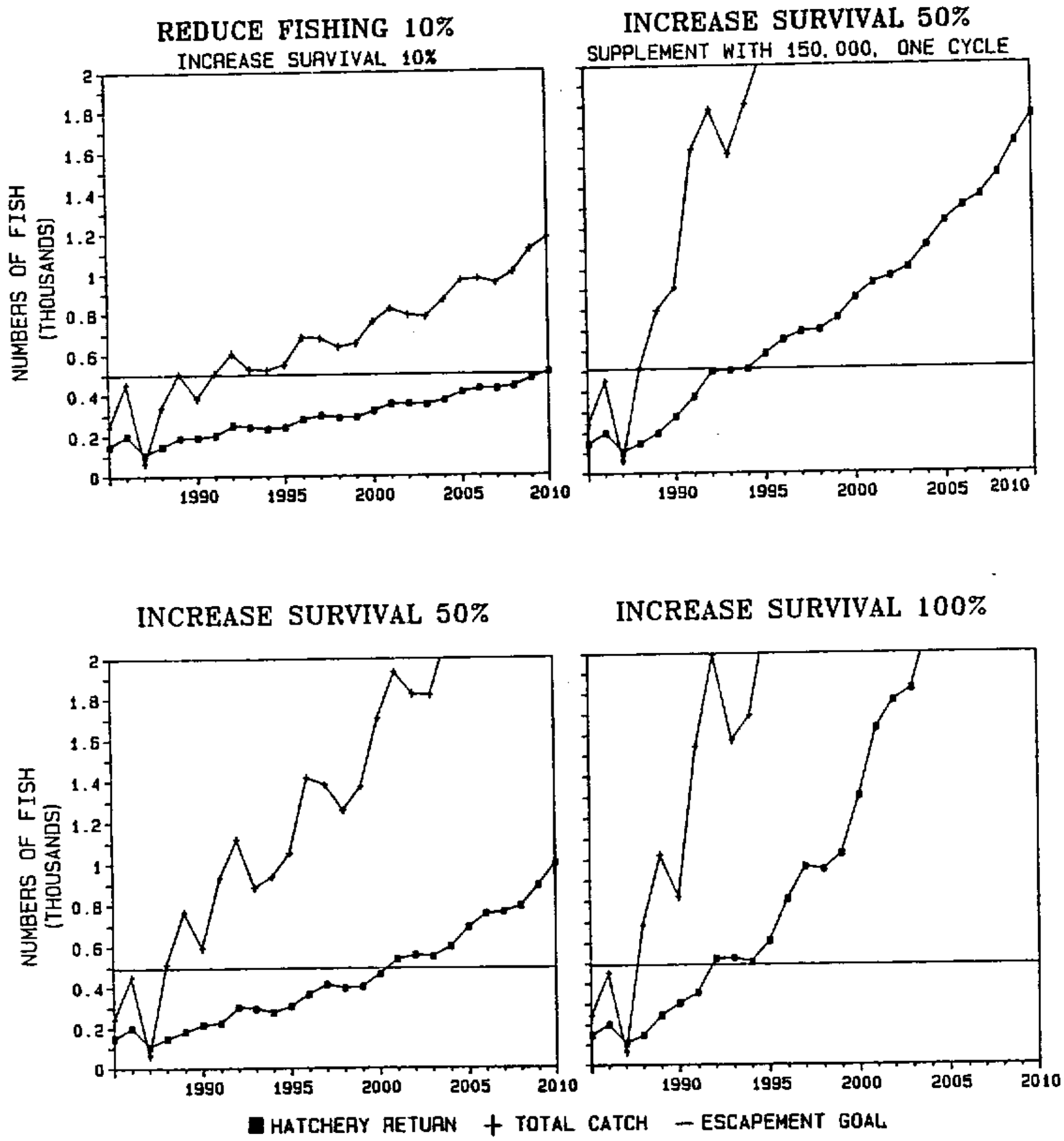

Figure 4 continued.

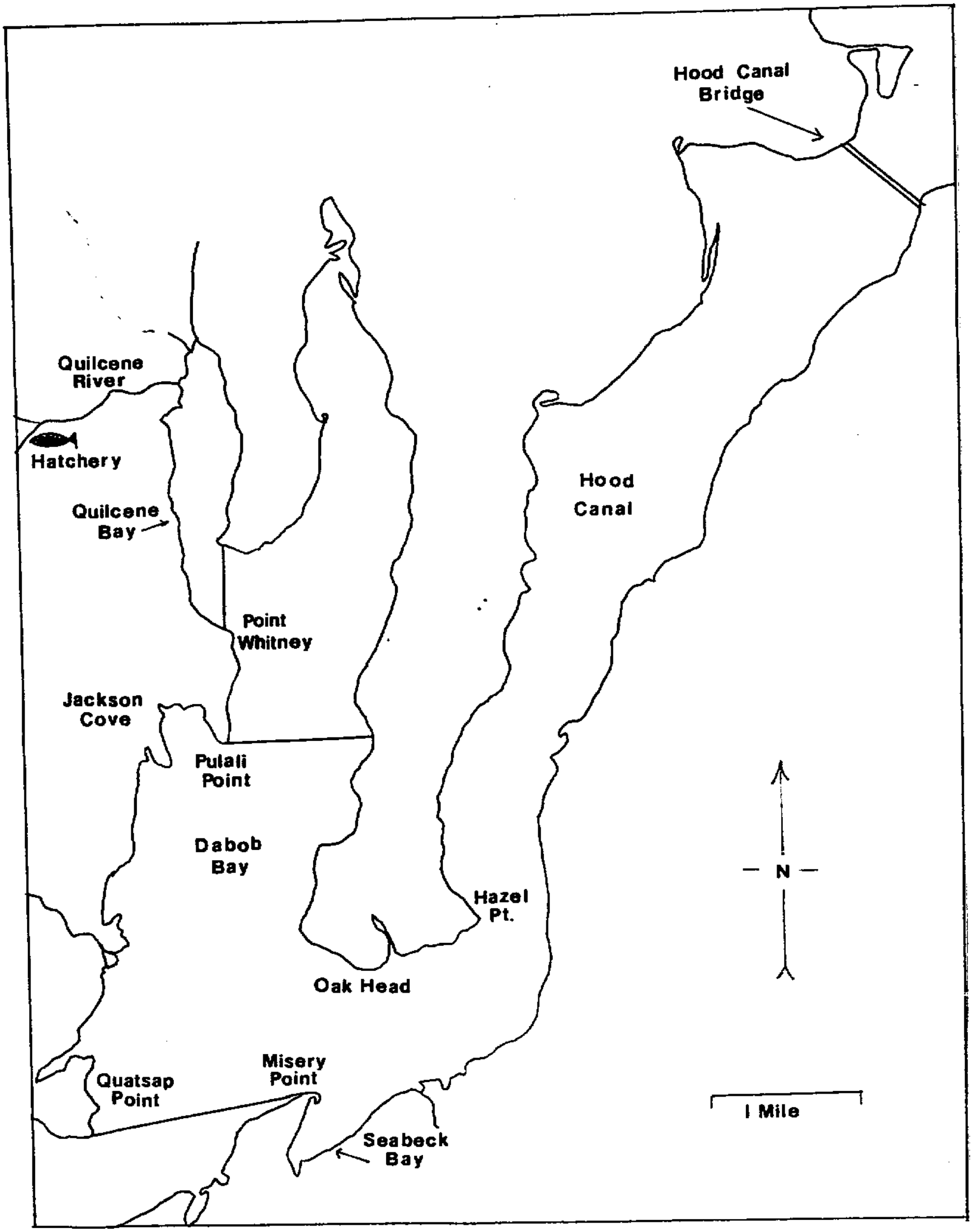

Figure 5. Map of northern Hood Canal showing Area 12 recovery sites and closed areas.