Perspectives on pink salmon and sea lice: scientific evidence fails to support the extinction hypothesis

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Abstract.

Using a Ricker (1975) model and escapement data for a subset of Broughton Archipelago, British Columbia watersheds, Krkošek et al. (2007) predicted that sea lice infections originating on Atlantic salmon (*Salmo salar*) farms will cause the extinction of pink salmon (*Oncorhynchus gorbuscha*) in the archipelago by 2010. The purpose of this paper is to examine this issue in the context of all of the escapement data available for the archipelago and to review additional scientific reports and information not discussed by Krkošek et al. (2007). Additional research during the last five years is not consistent with the Krkošek et al. (2007) conclusion that sea lice routinely cause in excess of 80% mortality of fry. Rather the literature reviewed herein indicates that pink salmon fry mount an effective immune response at sizes as small as 0.7 grams resulting in the rapid shedding of lice within two weeks. Pink salmon returns are shown to be highly variable throughout the Northeast Pacific in areas without salmon farms. Following periods of high abundance, pink salmon populations typically fall to low levels and they may remain depressed for several generations. However, in most cases, the populations then gradually increase to begin the cycle anew. An examination of returns to all of the documented Broughton Archipelago watersheds indicates that following exceptionally high returns in 2000 and 2001, the populations declined to very low numbers in 2002 and 2003. Contrary to the conclusions reached by Krkošek et al. (2007), Broughton pink salmon returns have steadily increased since then with no indication that they are threatened with extinction. Other unsubstantiated assumptions used in the Krkošek et al. (2007) are also discussed in light of additional scientific reports and theoretical considerations.

Introduction

Following the release in 2002 of the Pacific Fisheries Resource Conservation Council Advisory document (PFRCC, 2002), intensive research on sea lice and their interaction with wild and farmed fish in the Broughton Archipelago of British Columbia has been underway. A series of papers claiming that salmon farms are the cause of sea lice (*Lepeophtheirus salmonis* and *Caligus clemensi*) infections on pink salmon (*Oncorhynchus gorbuscha*) fry in the archipelago have been published (Morton et al., 2004; Krkošek et al., 2005, 2006). Krkošek et al. (2007) now claim that sea lice originating on salmon farms will result in the extinction of Broughton pink salmon stocks in the near future. This review, which is intended to expand the discussion by describing other peer reviewed papers and public information important to understanding the interaction between pink salmon, farmed fish and sea lice, to include the following considerations:

1. The variability of pink salmon returns throughout the North Pacific with particular emphasis on the Broughton Archipelago.

2. The general absence of mortality among juvenile pink salmon following controlled laboratory exposure to *Lepeophtheirus salmonis*.

3. The absence of a cause and effect relationship between sea lice infecting pink salmon fry and larval lice released from salmon farms.

4. A re-evaluation of trends in pink salmon abundance.

1. The variability of pink salmon returns throughout the North Pacific with particular emphasis on the Broughton Archipelago.

a. *Understanding the variability of pink salmon returns in the North Pacific is important to predicting future escapement.* As an example, pink salmon returns to the Kakweiken River in the Broughton Archipelago from 1953 through 1999 (Figure 1) have been characterized by repeated fluctuations from 800,000 fish in 1975 and 1983, to <100,000 fish in most years (Fisheries and Oceans Canada, 2007). Fluctuations in the abundance of returning pink salmon are also characteristic of another Broughton river, the Klinaklini (Figure 2). Even year pink salmon virtually disappeared from this river between 1974 and 1992. The population suddenly rebounded in 1998, which was eleven years after salmon farming began in the archipelago. The variability in returns of pink salmon fry is not unique to the Broughton Archipelago. Figure 3 describes pink salmon returns to the Duckabush River, tributary to Hood Canal in Washington State, where there have never been any salmon farms. Returns there have varied between 100,000 in 1963 and a very few thousand in 1975, 1981 and 1993. The point in this discussion is that extreme fluctuations in pink salmon returns are common, making assessments difficult. This point was emphasized by Mr. Bill Heard (NOAA Fisheries, Auke Bay, Alaska, personal communication) who noted that there was a "coast-wide collapse (at least in much of North America) of pink salmon returns in 2006. The 2006 forecast was for a harvest of around 40 million pinks (in Alaska), while the actual harvest was only 11 million due to the unusual low returns." Haeseker et al. (2005), Heard (1991) and Hard et al. (1996) provide reviews describing the extreme variability in pink salmon returns in the Northeast Pacific generally and the difficulty in forecasting future returns.

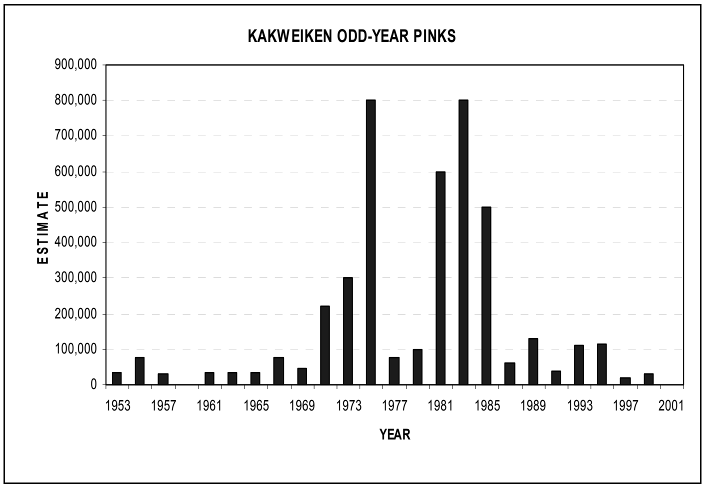


Figure 1. Odd year pink salmon (*Oncorhynchus gorbuscha*) returns to the Kakweiken River, tributary to Knight Inlet, British Columbia between 1953 and 2001 (Fisheries and Oceans Canada, 2007).

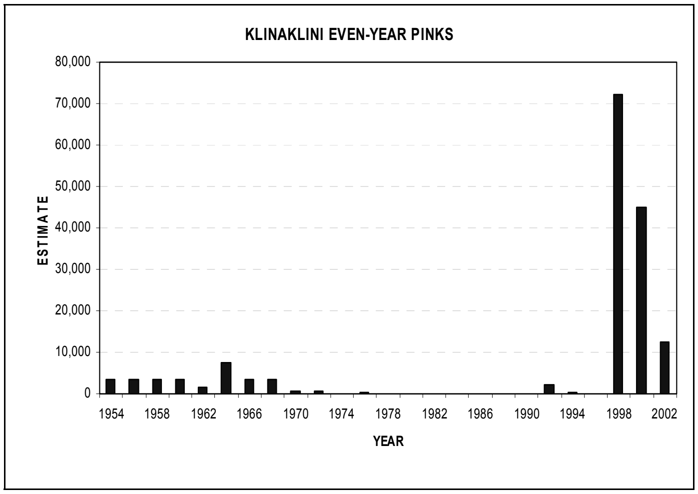


Figure 2. Historical pink salmon (*Oncorhynchus gorbuscha*) returns to the Klinaklini River, tributary to Knight Inlet, British Columbia in even years. (Fisheries and Oceans Canada, 2007).

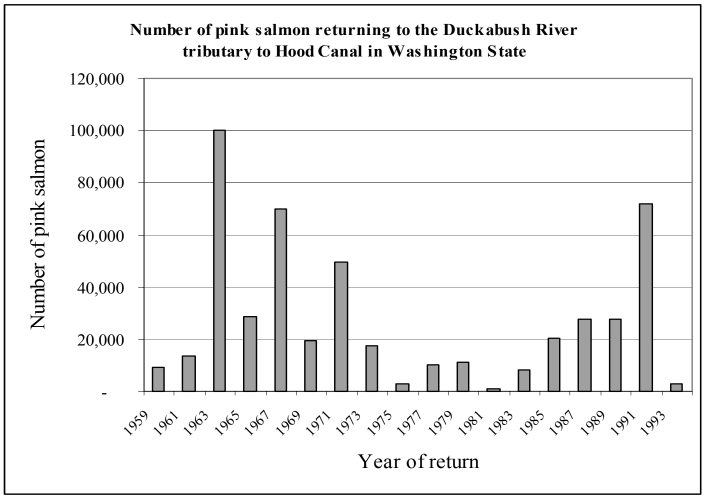
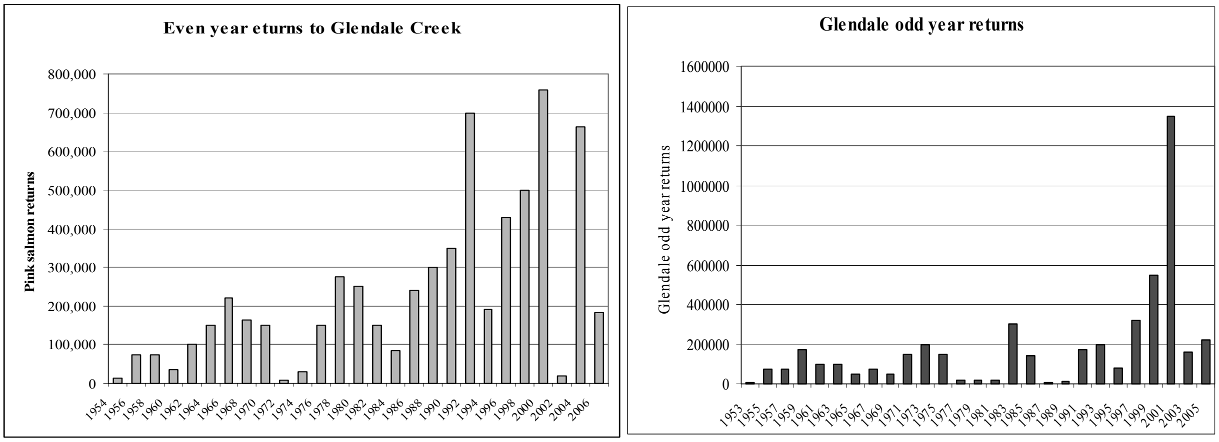


Figure 3. Historic pink salmon returns to the Duckabush River, tributary to Hood Canal in Washington State, USA. Only odd year runs are present in this river (7).

b. Exclusion of Glendale Creek data is inappropriate. Krkošek *et al.* (2007) excluded Glendale Creek escapement data because the watershed includes a spawning channel. However, they did include escapement form the Kakweiken River which also has a spawning channel. This is important because Glendale is the major pink salmon producing system in the archipelago. Between 1999 and 2005, it produced 89% of the Broughton pink salmon returns in odd years and 39% of the returns in even years. In addition, Krkošek et al. (2007) deals with marine survival, not freshwater survival, and recruits from Glendale affect marine population dynamics in all circumstances. Figure 4 describes the historic variability of pink salmon returns to Glendale Creek. The main difference in Glendale returns has been their increase after the initiation of salmon aquaculture in 1987 and the exceptionally high returns in 1992, 2000, 2001 and 2004. Returns since the sharp 2000 decline have been within the range of values seen before aquaculture began in 1987. Glendale returns are important to understanding pink salmon returns to the Broughton and exclusion of these data by Krkošek et al. (2007) is not justified by the presence of a spawning channel.



a) Even year returns

b) Odd year returns

Figure 4. a) even year and b) odd year pink salmon returns to Glendale Creek, the major pink salmon producing watershed in the Broughton Archipelago Fisheries and Oceans Canada. (2007).

2. Claims that pink salmon fry will suffer up to 97% mortality following infection with sea lice are not substantiated. Krkošek et al. (2007) claim that sea lice induced mortality was commonly 80% in fry and ranged from 16% to over 97%. Their assessment is based, in part, on earlier studies (Morton and Routledge, 2005; Krkošek et al., 2006), in which mortality among captive naturally-infected pink and chum salmon led the authors to conclude that “Farm-origin lice induced 9 – 95 percent mortality in juvenile pink and chum salmon”. The latter studies used wild-caught fish of unknown size and failed to control for alternative sources of mortality. In contrast, no evidence of mortality was observed among naïve pink salmon juveniles in controlled laboratory trials following exposure to *L. salmonis* copepodids (Jones et al., 2006b, 2007; Webster et al., 2007). Furthermore, patterns of gene expression showed that pink salmon mount an effective defense that accelerates the rejection of lice from their skin (Jones *et al.*, 2007). Recently, this innate resistance to sea lice was found to first develop in pink salmon between 0.3g and 0.7g and was associated with changes in skin development including the formation of scales (Jones et al., in-press a). In another study, the innate resistance to *L. salmonis* was retained in 3g to 13g pink salmon despite feed deprivation (Jones et al., in-press b). These observations are consistent with numerous earlier studies demonstrating a general resistance to sea lice infections among species of

Pacific salmon (*Oncorhynchus* spp.) (Johnson, 1993; Johnson and Albright, 1992a, 1992b; Fast et al. 2002a, 2002b). More research is required to characterize the risk associated with *L. salmonis* infection before migrating post-emergent pink salmon reach 0.7g (Jones et al., in press a). A significant reduction in the risk of death associated with sea lice due to innate resistance has a negative influence on the capacity of the model used by Krkošek et al. (2007) to predict population extinction.

3. ***No cause and effect relationship has been demonstrated between sea lice infecting pink salmon fry and larval lice released from salmon farms.*** Krkošek et al. (2007) assert that larval lice released from cultured Atlantic salmon are responsible for increased infections on pink salmon fry collected near the farms. This assertion is based in part on correlation analysis and in part on an assumption that there are no other significant sources of sea lice in the Archipelago. These assumptions ignore several important factors that are well documented in the literature.

a. *The "fallow route" described in Krkošek et al (2007) was not entirely fallow in 2003.* No empirical evidence of a "primary migration route" has been obtained in the Broughton and the migration of pink salmon fry is likely dependent on a number of fry density dependent factors. Atlantic salmon production in the Broughton Archipelago between 1998 and 2005 varied between 14,323,634 and 20,840,867 kg with a mean and 95% confidence interval of 17,360,469 ± 1,836,984. Production in 2003 (BC PSF, 2008) was 16,438,333 kg, which was not significantly different from the mean for the eight year period (single sample *t-test,* t = 1.19, p = 0.28). A portion of the pink salmon fry migrating westward down Knight Inlet from Glendale Creek and the Klinakini River encounter the Doctor Islet, Sargeaunt Pass and Humphrey Rocks salmon farms as they turn north into Tribune Channel where they join fry from the Kakweiken River (Figure 5). Doctor Islets produced 1,929,554 kg of marketable salmon in 2003 and the farm was not fallow until after April 18, 2003. Sargeaunt Pass and Humphrey Rock, located in the same area, were stocked in March and April of 2003. The presence of these stocked farms and the normal production levels in the Broughton Archipelago during 2003 jeopardizes a claim that the Tribune Channel migration path was fallow or that farm derived larval lice were reduced in 2003 compared with other years. In 2003, when Krkošek *et al.* (2007) saw significant reductions in sea lice infections, nauplii released from these three farms were competent to infect wild fish from Kumlah Island to the vicinity of the Glacier Falls farm. These fry continued migrating around Tribune Channel, including the area reported by Krkošek et al. (2007). Therefore, reductions in sea lice infections on pink salmon fry occurred in Tribune Channel despite the continued operation of salmon farms and consistent production of farmed salmon in the archipelago. The year 2003 is emphasized because these fry migrated to sea through the archipelago during a year when Atlantic salmon production was 16,438,333 kg and they experienced exceptional marine survival with good returns (950,288 pink salmon) in 2004 (Beamish et al. 2006). Atlantic salmon production in the Broughton Archipelago was actually lower in 2000 (15,575,808 kg) when the fish returning in the year of the 2002 decline migrated to sea.

b. *There is no evidence that a "pre-infestation period" actually existed***.** Comparison of "pre-infestation" growth rates with "fallow growth rates" or "exposed population" growth rates by Krkošek et al. (2007) is not valid because there are no inventories of sea lice on other species of fish or on salmon fry in the Broughton prior to 2001 and thus, there is no basis for assuming a that a "pre-infestation period" actually existed.

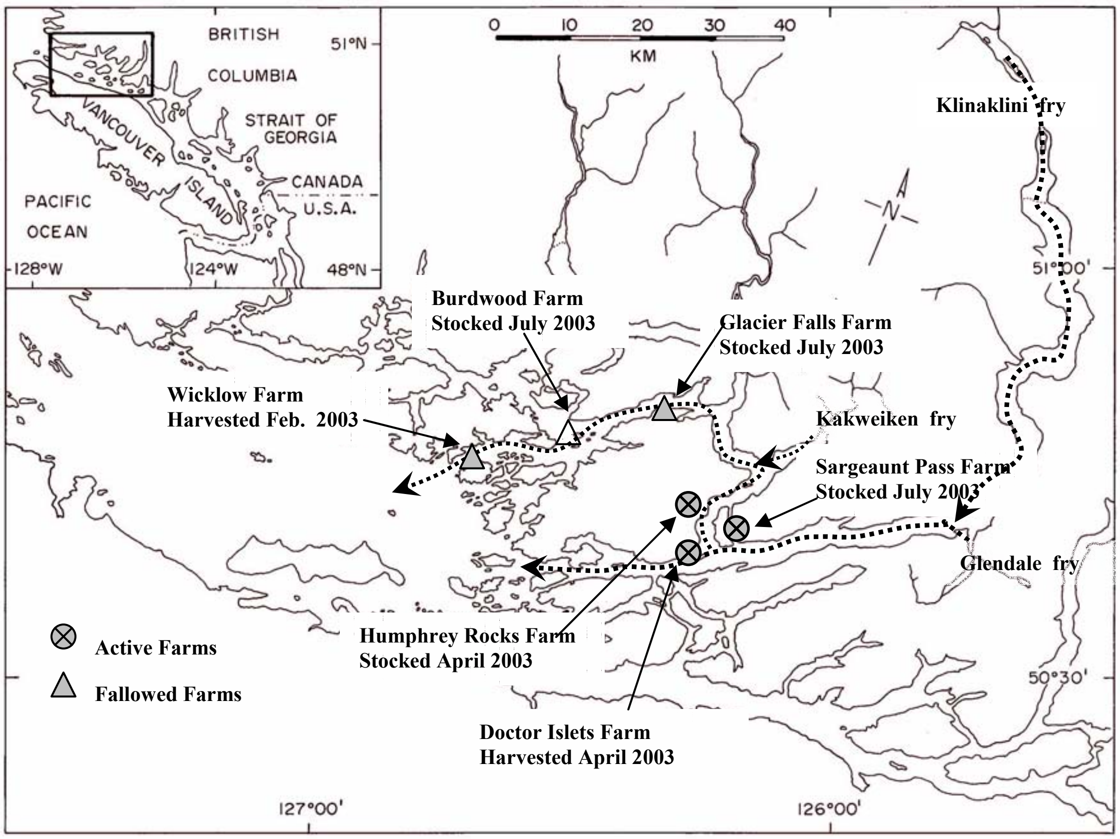


Figure 5. Broughton Archipelago showing two possible migration paths taken by pink salmon fry (dashed lines) and the location of three active salmon farms (Doctor Islets, Sargeaunt Pass and Humphrey Rocks) together with three inactive farms (Glacier Falls, Burdwood and Wicklow).

c. *Farmed salmon are not the only source of either C. clemensi or L. salmonis in the Broughton Archipelago. Caligus clemensi* has many wild hosts and farmed salmon are not the only source of larval *L. salmonis* in the archipelago. The authors ignore the work of Jones et al. (2006a) who reported significant abundance and intensity of both *C. clemensi* and *L. salmonis* on abundant populations of three-spine sticklebacks (*Gasterosteus aculeatus*) in the Broughton and of Trudel et al. (2006) who reported that approximately 25% of 284 juvenile pink salmon examined in the Eastern Bering Sea were infected with one to six sea lice with a mean intensity of 1.5 lice per infected fish. Trudel et al. (2006) concluded that, "This study demonstrated that salmon infested with lice remained in coastal waters throughout the year. We suggest that lice on salmon that overwinter in coastal waters will contribute to the infestation of salmon smolts migrating to sea in the spring through the release of lice nauplii in the water column." The point in this discussion is that we don't know what the relative contributions of *L. salmonis* or *C. clemensi* larvae are from farmed salmon in comparison with wild sources and it is misleading to assume that sea lice infections are associated primarily with nauplii released at salmon farms. Repeated attempts to collect significant numbers of nauplii or infective copepodids at or near salmon farms have failed. Salmon farms may contribute 99% of the larvae or they may contribute 1% and the answer eludes us. What is clear is that sea lice are found on juvenile salmon wherever we look in the Northeast Pacific and that there are numerous wild sources of these lice in addition to those contributed by salmon farms.

d. *The effects of salinity and temperature on development and survival of sea lice larvae are poorly documented***.** Krokošek et al. (2005, 2006, 2007), Krokošek and Lewis (2005), and Morton et al. (2004, 2005) have repeatedly asserted that their observations of increased sea lice abundance on pink salmon fry in the vicinity of salmon farms in comparison with their control sites indicates that the farms are the source of the infecting lice. Their control samples have been collected in areas of low salinity and they contend that *L. salmonis* larvae are not affected by salinities as low as 15 PSU (Morton et al*.,* 2005). That assertion is contrary to our current understanding of the life history of sea lice and hydrodynamics in the Broughton Archipelago (Brooks, 2005; Brooks and Stucchi, 2006). Science proceeds as other researchers attempt to duplicate the results of published work. Consistent with the seminal work of Johnson and Albright (1991), who observed almost no development to the *L. salmonis* copepodid stage at salinities <30 PSU, Bricknell et al. (2006) found that survival of free-swimming copepodids was "severely compromised" at salinity less than 29 PSU and Tucker *et al.* (2000) found reduced settlement of copepodids at 24 PSU in comparison with 34 PSU. Winter salinity in the Broughton approaches 30 PSU. However, salinity falls rapidly after April and is typically in the range of 15 to 25 PSU during late spring and summer in the eastern portions of the archipelago where these studies have been undertaken. This is another facet of the epizootiology of sea lice that Krkošek et al. (2007) fail to address in their model making their control data questionable.

*e. The dispersion of sea lice between hatching and molting to the infective copepodid stage are not considered in the models of Krkošek et al***.** *(2007).* In response to the assertions of Krkošek and Lewis (2005) that increased infection of pink salmon fry in the vicinity of salmon farms was caused by sea lice larvae originating on salmon farms, Brooks (2005) and Brooks and Stucchi (2006) used a Broughton specific hydrodynamic model (Foreman et al*.,* 2006) to show that larvae would be advected at least 10 to 12 km from the farms during development to the infective stage and that in some cases they were likely advected out of the estuary. The model used in their paper did not include the influence of wind on resting current vectors. However, an analysis of empirical current data, that does include the effects of wind, from 15 farms in the archipelago indicated that maximum current speeds at every farm were between 50 and 75 cm/sec and that resting currents vectors integrated over full lunar cycles carried imbedded particles toward Queen Charlotte Strait at a mean speed of 1.99 cm/sec or 6.8 to 10.3 km during development to the copepodid stage. Gillibrand and Willis (2007) have developed a model to predict the dispersion of larvae from salmon farms or other sources of nauplii. Their model includes sea lice behavior, mortality as a function of salinity, development time as a function of temperature, and wind, river discharge, and tidal currents. Consistent with Brooks (2005), their model predicts that larvae will molt to an infective stage at distances of 7 to 12 km from the point where they hatched. Gillibrand and Willis (2007) note that their predictions are consistent with field observations of copepodids. None of this contradictory evidence is discussed by Krkošek et al. (2007) nor do they describe how it affects their model. Basic considerations of sea lice life history and currents suggest a very small likelihood that sea lice larvae are retained in the area where they hatch for four to six days while they develop to an infective stage. This conclusion has now been reached by several other researchers in various parts of the world. Krokošek and colleagues have refused to acknowledge criticisms of their model (Brooks, 2005; Gillibrand and Willis, 2007) or to demonstrate any cause and effect relationship between their identified zones of infection and sea lice originating on salmon farms.

f. There is no consideration by Krkošek et al. (2007) that salmon farms have been using prophylactic applications of emamectin benzoate to manage sea lice infestations since 2004. These prophylactic treatments have resulted in farm lice infestation decreasing during the migration season. Krkošek et al. (2007) assume a steady state lice dispersion model. This assumption cannot be validated and the model should have been relaxed to accommodate the temporal dynamics of sea lice populations available for salmon farms in the Broughton. As a result, Krkošek et al. (2007) have overestimated the production of sea lice nauplii on farms.

4. Analysis of the entire pink salmon database supports conclusions opposite to those reached by Krkošek *et al.* (2007)

a. *Misleading regression analysis.* Krkošek et al. (2007) used linear regression to fit a log-transformed subset of normalized escapement data to the Ricker model. Populations of pink salmon were grouped by assuming they had experienced various levels of sea lice exposure. Even a cursory examination of the data in Figure 3 of their paper suggests that a non-linear regression would have been more appropriate and that a properly fitted response would asymptotically approach values that are near zero but slightly negative for all of the modeled populations. In addition, the authors did not provide coefficients of determination for the regressions. The scatter in Figure 3 suggests that the linear solution explained very little of the variability in the database. In addition, the data in Figure S1, describing escapement since 1970, should have been analyzed using an appropriate regression model to determine if the coefficients on time were significantly positive or negative or not significantly different from zero.

b. *Incomplete model.* Krkošek et al. (2007) evaluated pink salmon population dynamics over time using the Ricker (1975) model. In their model $n_i(t) = n_i(t - 2)\exp[r – bn_i(t – 2)]$, where n_i is the number of pink salmon in cohort (i); t is the time at which the estimate is made; (t – 2) is the spawning cohort producing the generation in question, r is the population growth rate and $bn_i(t-2)$ represents losses in cohort n due to density dependent mortality. To be biologically meaningful, the density dependent mortality should have been expressed as $\Sigma b_j n_i(t-2)$. There are numerous factors affecting freshwater and marine survival of pink salmon (Heard, 1991; Friedland et al., 2003). Freshwater survival includes random mortality effects and density dependent effects (number of spawners, etc.). Mortality factors affecting pink salmon fry during their nearshore marine residence include both fresh and marine water quality (b_{wq}), predation, and several density dependent factors such as food availability (b_f), horizontally transmitted disease agents (b_d) and random disease effects, such as sea lice infections (b_{sl}). Collectively, these factors contribute to the 55 to 77 percent mortality expected during the early marine life of pink salmon (Heard, 1991). A more appropriate model would be of the form $n_i(t) = n_i(t - 2)\exp[r – \Sigma b_j n_i(t - 2)]$ where the b_j include at least the density dependent factors cited above. There is no doubt that the historic return of 3,600,000 pink salmon to the Broughton Archipelago in 2000 collapsed in 2002. Since every system has a carrying capacity it is reasonable to hypothesize that the unprecedented return of 3.6 million pink salmon to the Broughton Archipelago in 2000 exceeded the available spawning habitat in freshwater and the carrying capacity of the marine environment during the 2001 out-migration of fry. Bugaev (36) noted a similar collapse in an area of Russia where there were no salmon farms and concluded that, “Due to overflow of the spawning grounds almost the whole generation of pink salmon of the Western Kamchatka of 1983 died.” The conclusion by Krkošek et al. (2007) that sea lice infections derived from farmed salmon caused the reduced population growth rates (r) observed during the “exposed period” is not substantiated in the paper by any cause and effect relationship and there could have been many causes of the low returns in 2002. A serious error of omission is failure to include and discuss these other causes of mortality resulting in an incomplete model and misleading results.

c. *Selective use of data.* Figure 6 describes pink salmon returns to Broughton Archipelago watersheds between 1953 and 2006. Salmon farming began in 1987 and pink salmon returns increased during the next 13 years. The solid arrows indicate historic periods of even year pink salmon declines and the dashed arrows indicate odd year declines. An analysis that is restricted to any of these periods, for instance between 1976 and 1984 or between 1983 and 1991 could be interpreted as evidence that the stocks were headed for extinction. However, in each case, pink salmon returns to the Broughton Archipelago bottomed and then increased to at least their long-term average number, just as they are now increasing since the low returns of 2002 and 2003.

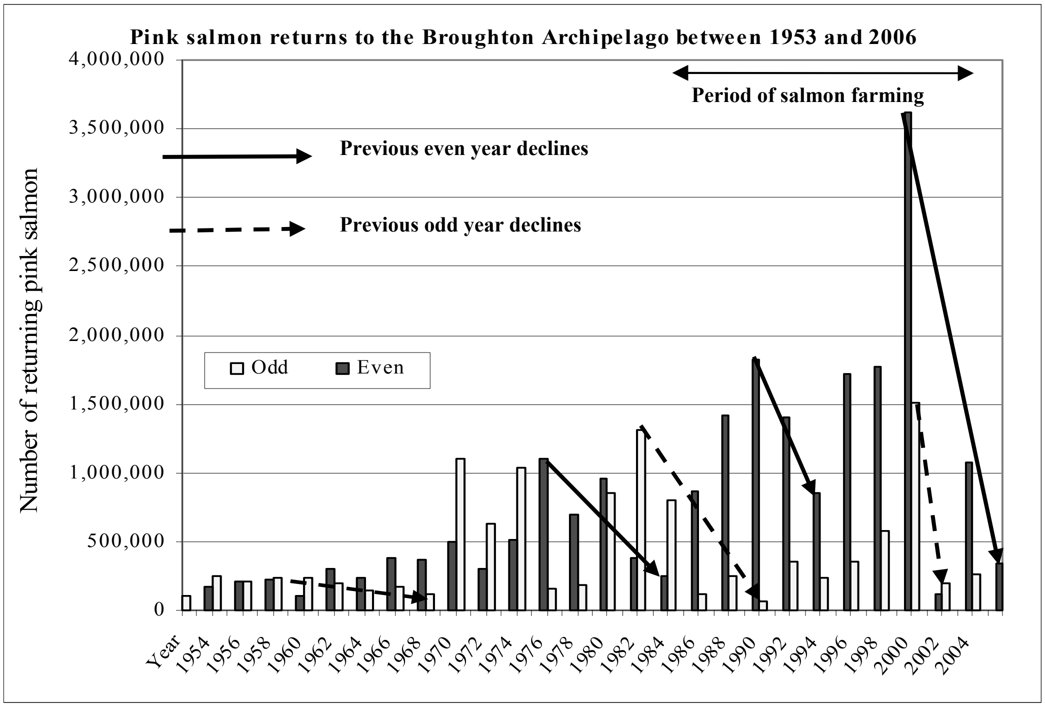


Figure 6. Even and odd year pink salmon returns to Broughton Archipelago watersheds between 1953 and 2006. Arrows indicate periodic declines that, when analyzed over short periods of time, could be used to predict the extinction of pink salmon stocks (3).

d. *Incomplete analysis.* Figure 7 describes total returns to the 11 Broughton watersheds included in the Fisheries and Oceans Canada escapement database for Area 12 (Broughton Archipelago) from 1999 (before the 2002 decline) through 2006 (Fisheries and Oceans Canada, 2007). For this analysis, the independent variable year was converted to years since 1998 and $\log_{10}(N+1)$ transformed to normalize the residuals. The data was then analyzed using non-linear regression (Statistica, Version 6). A linear model such as used in Krkošek et al. (2007), is included in Figure 7. Note that the non-linear polynomial has a coefficient of determination of 0.55. Krkošek et al. (2007) did not provide details describing their regression analyses, but the linear regression for this un-normalized, but log transformed data, resulted in $r^2_a = 0.29$ and the coefficient on time was not significant ($p = 0.18$). Of greater importance in Figure 7 is the shape of the curves. The linear regression approach similar to that used by Krkošek et al. (2007) suggests that pink salmon populations are declining and the trend would predict their eventual extinction. The polynomial fit suggests a very different scenario in which the unprecedented returns in 2000 and 2001 were followed by significant reductions in 2002 and 2003. However, as has been seen repeatedly in pink salmon populations, the trend since 2003 has been positive with increasing returns suggesting that Broughton populations are recovering from the unknown causes of the 2002 and 2003 lows. A scholarly manuscript would have discussed these alternate analyses and the authors would have justified their conclusions in light of all of the evidence.

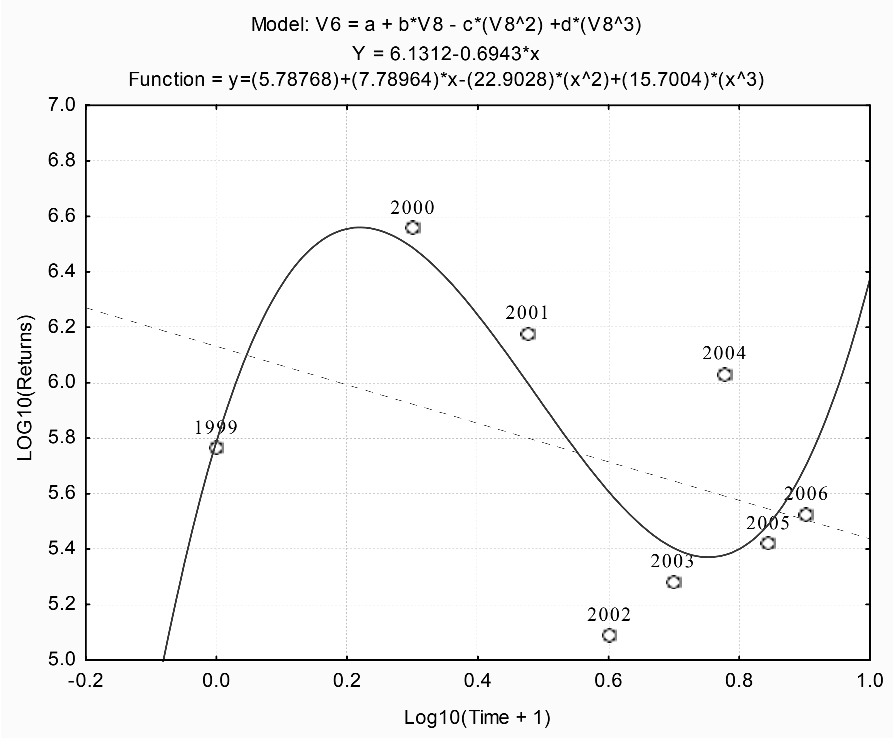


Figure 7. Log_{10}(Broughton pink salmon escapement) since from 1999 through 2006 as a function of time. Values have been Log_{10} transformed. The coefficient of determination for the polynomial is $R^2_a = 0.55$ whereas R^2_a for the linear regression is 0.29. However, other than the constant, none of the regression coefficients were significant suggesting no significant trends.

e. *Current trends in pink salmon returns.* The Broughton data for both odd and even years between 2002 and 2006 is summarized in Figure 8. Consistent with total returns, data for the highest producing pink salmon watershed in the archipelago demonstrates a trend to increasing returns after 2002. The exceptionally high return in 2004 resulted in a poor fit with $r^2_a = 0.04$ and a non-significant coefficient on the independent variable year. If the exceptionally high returns in 2004 are excluded as an outlier (Beamish et al., 2006), a significant ($p < 0.05$) positive trend is demonstrated with a predicted increase of 49,818 pink salmon each year and a coefficient of determination of $r^2_a = 0.98$. Marine survival of pink salmon returning to Broughton watersheds has been 1.0 to 23% (2004 = 23%; 2005 = 3.4%; 2006 = 1.0% and 2007 = 2.6%). Pink salmon marine survival for Fraser River pink salmon is typically 1.2% and it averages 2 to 3% coastwise (R. Beamish, personal communication). Therefore, survival has been equal to or better than observed for the Fraser River and the rest of the British Columbia coast during the last four years. It has been 6 years (2002 through 2007) since Broughton Archipelago pink salmon stocks declined sharply in 2002. By examining a subset of the pink salmon watersheds in the archipelago, Krkošek et al. (2007) claim that louse-induced mortality of pink salmon is commonly over 80%, and they expect a 99% collapse in pink salmon population abundance in four salmon generations (8 years). An examination of Figures 4, 6, 7 and 8 suggests that current returns are within the historic variability of the archipelago, and that since 2002, the population growth trends are positive, not negative as suggested in Krkošek et al. (2007).

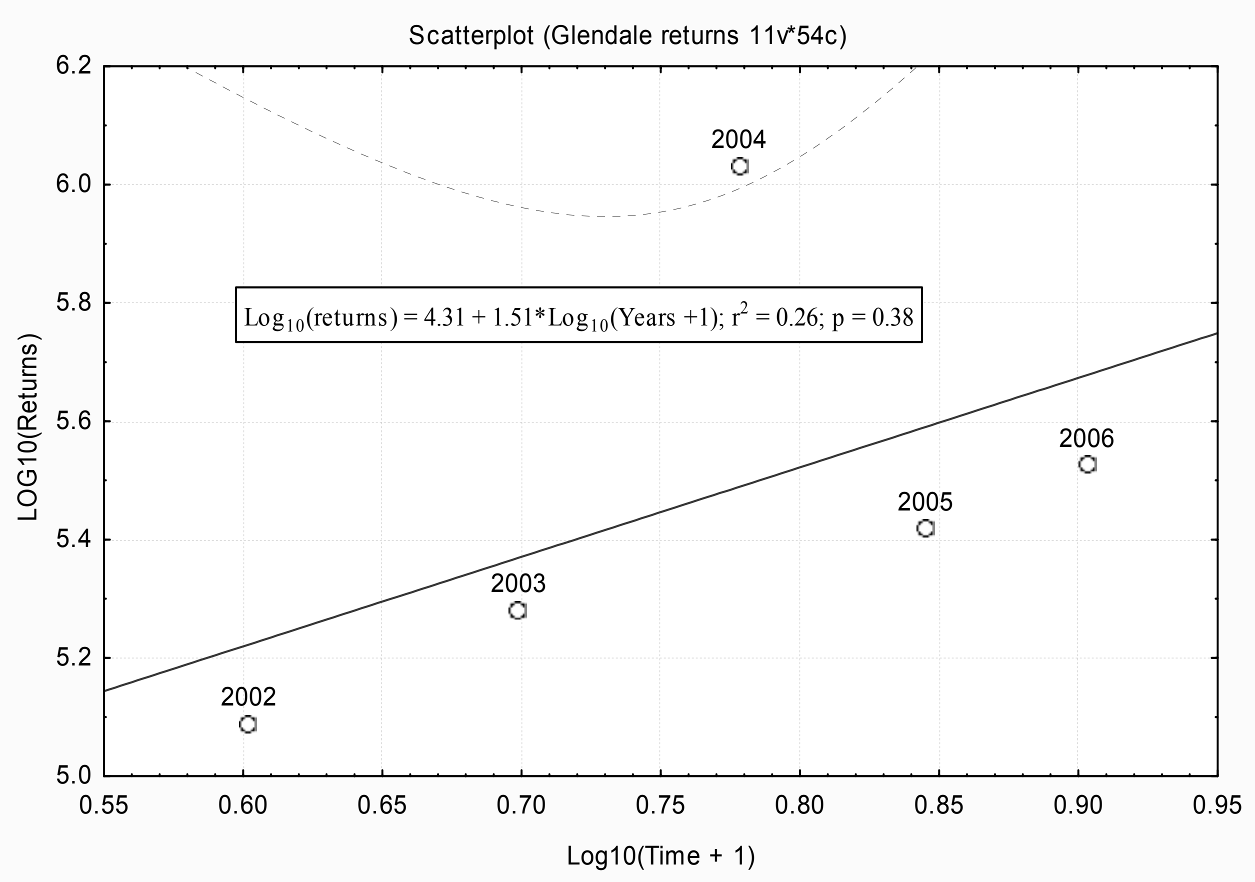


Figure 8. Linear regression describing trends in pink salmon returns to Broughton watersheds from 2002 through 2006. Note that the exceptionally high 2004 returns are included in this figure.

Summary. By selective use of data, questionable analytical procedures and several unsubstantiated assumptions presented as fact, Krkošek et al. (2007) predict the extinction of pink salmon stocks in the Broughton Archipelago within four generations (8 years). The authors failed to acknowledge and review the work of numerous scientists from around the world whose results do not necessarily support their conclusions. They have failed to present alternative hypotheses and analytical approaches or to discuss how these might influence their conclusions. Research to this date indicates that pink salmon fry mount an effective response to sea lice infections. Pink salmon escapements typically fluctuate dramatically throughout the Northeast Pacific. Stocks of these fish reached unprecedented levels in 2000 and declined sharply in 2002 for unknown reasons. When all of the Broughton's watersheds are considered, pink salmon stocks are seen to have steadily increased over the last five years with no indication that they are headed for extinction. The purpose of this paper is not to deny that salmon farms may contribute sea lice to the marine environment. The fact is that at this time research has not determined the relative contribution from wild and farmed sources of lice. Rather, this discussion is intended to provide additional information giving readers a broader perspective of these issues.

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