Session 4b: Effects of anthropogenic and environmental factors on age and size at maturity. (prepared by Kathryn Kostow)

Greg Ruggerone (Natural Resources Consultants, Inc.): *Density-dependent growth, maturation, and survival of Chinook salmon at sea.*

- Evidence for density-dependence at sea has been demonstrated in studies of the effects of alternate year abundance of pink salmon on other salmon species. Higher fish abundance corresponds to:
  - Reduced growth;
  - Reduced survival;
  - Increased age at maturation;
  - Decreased productivity corresponding with older age at maturation;
- Salmon abundance can correlate with secondary production at sea, as indicated by copepod indices;
- Climate may exacerbate species interactions;
- Density-dependence can also occur in fresh water environments;
- Growth, survival and maturation in the sea can be affected by previous experience in fresh water environments;
- Growth and size differ by gender; effects on female fecundity may particularly affect population productivity.

Jeff Hard (NMFS): *The demographic and evolutionary implications of harvest for age and size at maturation in Chinook salmon.*

- Fisheries management's focus on yield ignores evolution.
  - Selective harvest is likely to induce adaptation
  - High harvest mortality may destabilize population dynamics
- Traits potentially affected by harvest:
  - Evolutionary response in size and age at maturation
  - Fertility and egg size
  - Growth rates, consumption and foraging behaviors
  - Survival rates
  - Vertebrae counts
  - Migration routes and timing
  - Sexually selected traits
- Fitness is influenced by conflicting effects of natural and harvest selection
  - Environmental variation also influences life history expression
  - Evolutionary effects of harvest depend on relationship between size and age at maturation
    - If maturation is constrained more by size: faster growth and earlier maturity
    - If maturation is constrained more by age: slower growth and later maturity
- Evidence for harvest-induced evolution in salmon
  - Predominant removal of larger fish
  - Evidence for heritability of size and age
  - Observations of changes in traits expected to be affected by harvest
    - An association between decreasing body size and declining abundance observed in Alaskan Chinook
    - An association between harvest rates and coho size observed in Washington

        - Higher ocean fishery mortality on older fall Chinook observed in Oregon stocks
        - Pacific chum are becoming smaller and older
        - Changes in age or size at maturation commonly observed in exploited stocks
        - Changes observed in run and spawning time
- Modeling can be used to explore a population's response to harvest selection
    - Changes in size, age and fertility
    - Association with population demographics and productivity
    - Responses to changes in harvest management
    - Some observed responses differ from model predictions—are the models too simplistic?
- What are the implications for sustainable fisheries? Two unresolved questions:
    1. Does fishing-induced evolution matter for sustainable harvest management?
    2. Is a more precautionary approach warranted? If so, what should it entail?

Neala Kendall* (UW), Jeff Hard (NMFS), and Tom Quinn (UW): *Changes in age and size at maturity related to fishery selection: lessons learned from Alaskan populations applied to Columbia River Chinook salmon.*

- Life history traits of harvested populations change faster over time than traits of wild populations that are not exploited. These changes can lead to less sustainable populations.
- Ricker introduced the idea that fishery selection was correlated with trends towards smaller size and younger age at maturity in Pacific salmon.
- Selection differentials (SD's) are the differences in the average value of a trait between all fish that escape a fishery (fish available for reproduction after harvest) and all fish before they enter a fishery (all adult recruits before harvest). SD's be calculated as the product of harvest rates and the selectivity of a fishery (comparison of caught vs. not caught traits) and can be used to quantify fishery selection.
- Both commercial and recreational fisheries can cause fishery selection and the selection differentials are additive.
- The effects of fishery selection under variable environmental conditions can be analyzed using probabilistic reaction norms and quantitative genetic models.
- Data are available to calculate the fishery selection of at least some of the Columbia River Chinook fisheries.

Tom Cooney (NMFS): *Differences in Fishery Selectivity on Male and Female Snake River Fall Chinook Salmon.*

- Length frequency and age distributions of Snake River Fall Chinook taken in Columbia River fisheries were compared to fish that escaped the fisheries using coded-wire tag groups in return years 2000 - 2003. Escapement was measured at either Lyons Ferry Hatchery or at Lower Granite Dam.
- Relatively higher harvest rates occurred on larger fish as measured by length.
- Relatively higher harvest rates occurred on older fish. This effect was strongest in males where the highest harvest rate was on age 4 fish while age 2 males largely escaped the harvest.
- The net fisheries and recreational (hook and line) fisheries appear to have similar patterns of selectivity.
- This study did not look at the effects of the ocean fishery on Snake River fall Chinook.

Steve Haeseker (USFWS) and Jack Tuomikoski (FPC): *An evaluation of the effects of outmigration experience on age-at-maturity*

- A series of analyses were conducted using eight hatchery and two wild stocks of PIT-tagged spring/summer Chinook within the Columbia River Basin.
- Those analyses found:
    - PIT tag analysis of spring Chinook salmon that out-migrated under varying in-river experiences detected no difference in age at maturity for transported (i.e., barged) verses in-river migrants;
    - For in-river migrants, variability in age at maturity was not associated with in-river or ocean survival rates;
    - None of the 10 stocks showed an association between age at maturity and smolt-to-adult return rates (SARs);
    - There was a high degree of co-variation in age at maturity across Columbia River Basin stocks, and between hatchery and wild stocks, suggesting that large-scale factors are influencing basin stocks similarly;
    - Most of the variation in age at maturity was accounted for by stock effects and outmigration year effects;

William Connor (USFWS): *Effects of Dam Construction on Juvenile Life History Diversity and Age and Size at Maturity of Wild and Natural Snake River Basin Fall Chinook Salmon*

- Prior to anthropogenic activity including dam construction, the potential for both subyearling and ocean entry by wild juvenile fall Chinook salmon from the Snake River basin was high.
- The construction of dams on the mainstem Snake River, starting with Swan Falls Dam constructed in 1901, blocked and inundated significant spawning habitats for Snake River fall Chinook salmon. There were initial attempts to provide fish passage at Oxbow and Brownlee dams; however these efforts were discontinued after 1963.
- Juvenile passage data are available from the period when passage was provided. These data provide information about the size and migration timing of juvenile fall Chinook, circa 1960s and indicate that the potential for both yearling and subyearling migration tactics were apparently present, but environmental conditions produced by dam construction favored the subyearling tactic.
- Historic data on adult fork length and age are also available from spawning grounds upstream of Brownlee Reservoir.
- Spawning habitat has been confined to the area below Hells Canyon Dam since the mid-1960s, including mainstem and lower tributary reaches.
- Subyearling and yearling out-migrants are now being observed, as indicated by PIT tag detections at Lower Granite Dam and by age data from returning adults.
- The yearlings appear to come primarily from the Clearwater where summer flow augmentation from Dworshak Dam decreases summer water temperatures, improving survival but decreasing growth rates.
- The relative incidence of subyearling and yearling ocean entry in returning adults suggests that both migration tactics are important to adult returns.
- Adults produced by yearling juveniles tend to be smaller than those produced by sub-yearling juveniles, probably because yearling juveniles exchange a year of ocean-rearing for freshwater-rearing.

- Females from yearling juveniles are predicted to less fecund than those from sub-yearling juveniles.
- Modeling indicates that yearling migrants have relatively higher fitness under current dam operations. Management decisions about future dam operation and habitat management needs to favor a balanced juvenile life history to optimize total population fitness.

Robin Waples (NMFS), Anna Eiz (NMFS) and Bill Arnsberg (Nez Perce Tribe): *The shift toward yearling smolts in Snake River fall Chinook salmon: evolution or phenotypic plasticity?*

- Snake River fall Chinook juvenile life histories have changed in recent years. Historically they were largely subyearling migrants; currently about a quarter or more are yearling migrants, depending on the year and location.
- There is evidence of positive selection favoring yearling life histories, as indicated by adult returns, even after accounting for effects on age structure and fecundity.
- According to the most widely accepted model, the change is associated with juvenile growth rates, with faster-growing juveniles being more likely to reach a threshold for smolting as subyearlings. The change in growth rate could be due to evolution (genetic change over time), or it could be due to plasticity (the same genotypes doing different things in different environments).
- To distinguish between these possible mechanisms, a study was conducted to determine whether the juvenile life history of parents predicts the juvenile life history of offspring. Eventually adult-adult comparisons will be done; at present, juvenile growth rate is used as a proxy for juvenile migration life history.
- We found that parents that outmigrated as subyearlings generally produced faster growing offspring than parents that outmigrated as yearlings, and heritability of juvenile growth rate was apparently high.
- We also found an unexpected result: parents who were forced yearlings in hatcheries produced the fastest-growing offspring.
- There appears to be a weak parental effect on juvenile migration life history, but there is also evidence for a hatchery rearing environmental affect. In either case, the altered life histories expose the offspring to different selection regimes and can have evolutionary consequences.

Kathryn Kostow* (ODFW), Henry Yuen (USFWS), and Chris Kern (ODFW): *The quest for environmental and anthropometric variables that explain annual variation in upriver spring Chinook age structure.*

- The relationship between age 3 and age 4 upper Columbia Spring Chinook is used to forecast adult run size to the river. Since brood year 1997, this relationship has been unpredictable using simple age-class linear regressions;
- Alternative models that incorporate anthropomorphic and environmental variables that may affect age at maturity and/or age-class survival are being explored in an effort to explain the relationship and improve forecasting;
- Useful variables and models would significantly explain some of the variation in the relative returns of age 3s and 4s, and would have better predictive power than past models;
- Hatchery effects, where hatchery programs produce relatively more age 3 fish than wild populations, appear to be implicated but have been difficult to model;

- Variables that correlate with variation in age class survival in both freshwater and ocean environments are promising;
- Unpredictability is problematic only when age 3 abundance exceeds 10,000 fish. Density dependence, possibly in the ocean, may be implicated;
- Alternative non-linear models, particularly logarithmic models are very promising.

Related Discussion from Session 5 (Day 3): *What have we done to address management <u>problems related to age/size at maturity, and what should we do in the future?</u>*

- Fisheries may impact age and size structure. Are the fisheries that take Columbia River Chinook having a selective effect on populations?
- Should slot fisheries that protect older / larger fish be considered to avoid effects? However many fisheries are now catch-and-release for wild fish (even net fisheries) and only hatchery fish are taken. The primary purpose of many of these hatchery programs is to provide fish for the harvest and the most desired and valued fish in the harvest are the large ones. How should these considerations be balanced?
- What are the implications for sustainable fisheries? Two unresolved questions:
  1. Does fishing-induced evolution matter for sustainable harvest management?
  2. Is a more precautionary approach warranted? If so, what should it entail?
- The implications of changes in size and age for wild population viability and recovery warrant further study.
- Environmental and feed contaminants, especially steroids, warrant more exploration and attention. What are those doing to age at maturity?
- We should explore ocean conditions further.
  - What ocean window is determinant?
  - Is there an effect of ocean conditions a year prior to smolt entry to the ocean?
  - Can we detect the effects on changing trophic levels in the ocean?
  - More study is needed on interactions between fish condition, freshwater environment and ocean variables.
  - More study is needed on what influences survival between older age classes in the ocean (age 3 to 4; age 4 to 5).
- What is the relationship between the environmental variation and hatchery practices?
- What is the natural age structure in our wild populations? We may know something about distressed populations, but what is the age and size structure of a healthy wild population?
- We need to take a wider look at age at maturity beyond looking at what goes on in a hatchery and hatchery practices. Hatchery practices may be implemented in the increased occurrence of jack (age 2 or 3) fish in hatcheries compared to wild populations. However there is evidence of a decline in older/larger fish (ages 5, 6 and 7) that is likely not explained by hatchery practices. We still cannot explain why there is such an unpredictable relationship between age 3 (jack) and age 4+ (adult) fish at higher abundances.

Recommendations (?): Does the information presented in the session point to any preliminary or even more solid recommendations for weir operations, hatchery broodstock management, harvest, etc.?