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Salmon as Status Indicators for North Pacific Ecosystems

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Abstract: A new system of salmon status categorization will provide useful indicators of ocean conditions and climate variability in the North Pacific Ocean. Under Canada's new Wild Salmon Policy, biological status will be assessed and categorized for a few hundred largely independent lineages of chinook, sockeye, coho, chum, and pink salmon. Changes to the status of these Conservation Units, information regarding their oceanic distribution, and biological characteristics of fish returning to fresh water to spawn will be linked to the status of marine ecosystems. Data from short-lived species like pink salmon will inform the management of longer-lived species, including fish other than salmon. Each Conservation Unit will be categorized into one of three status zones based on the abundance and distribution of spawners or proxies thereof. Intensive studies of salmon returning to selected streams will determine the relative importance of factors operating in fresh versus oceanic waters and the role of natural vs. anthropogenic factors (e.g. fishing) on Conservation Unit status. These types of information collectively should provide important clues to marine health and carrying capacity. Things should also work the other way—ecosystem data (including oceanographic) will aid in the management of salmon and other marine species.

Keywords: salmon status, marine ecosystems, North Pacific, wild salmon, Pacific salmon, wild salmon policy, marine health

INTRODUCTION

Fisheries and Oceans Canada (DFO) released a major new conservation policy for wild Pacific salmon in June 2005 (DFO 2005). The goal of the Wild Salmon Policy (WSP) is "to restore and maintain healthy and diverse salmon populations and their habitats for the benefit and enjoyment of the people of Canada in perpetuity". Wild salmon diversity will be safeguarded by protecting Conservation Units (CUs), which are groups of wild salmon living in an area sufficiently isolated from other groups that, if they are extirpated, that area is very unlikely to be recolonized naturally within an acceptable timeframe (e.g. a human life time).

This paper will briefly introduce the WSP, explain CUs, and discuss linkages between the status of wild salmon and North Pacific ecosystems.

CONSERVATION UNITS

CUs define geographically or genetically distinct groupings of salmon that generally constitute irreplaceable lineages. A taxonomic species of Pacific salmon contains more than one CU; the spatial extent occupied by a species and the genetic diversity within it are greater than for one CU (Fig. 1). Populations (reproductive groups of salmon that are relatively isolated from other such groups), demes (groups of salmon at persistent spawning sites that are likely to breed with each other), and eventually pairs of spawning salmon will normally occur further along this continuum of decreasing diversity. DFO is in the process of delineating CUs for all species of salmon within British Columbia and the Yukon Territory.

The geographic extent and number of CUs will vary among species. CUs will be identified based on biological information, including genetic variation and phenotypic traits (e.g. run timing, life-history traits, oceanic distribution), major habitat breaks representing different adaptive environments, zoogeography, and aboriginal traditional knowledge. Genetic information suggests that we should expect more CUs for sockeye salmon (*Oncorhynchus nerka*) than for other species, and that most of these will be found at the level of individual rearing lakes or rivers. Because of their varied life histories, chinook salmon (*O. tshawytscha*) will have more CUs than coho (*O. kisutch*), chum (*O. keta*), and pink salmon (*O. gorbuscha*), and the freshwater area occupied by chinook salmon CUs will therefore tend to be smaller. The freshwater environment is less important than the ocean in the definition of CUs for pink and chum salmon. These CUs will be less numerous and will coincide with salmon living in aggregates of streams that flow through major coastal regions, such as those described by Augerot et al. (2005). There will be more pink CUs than chum because

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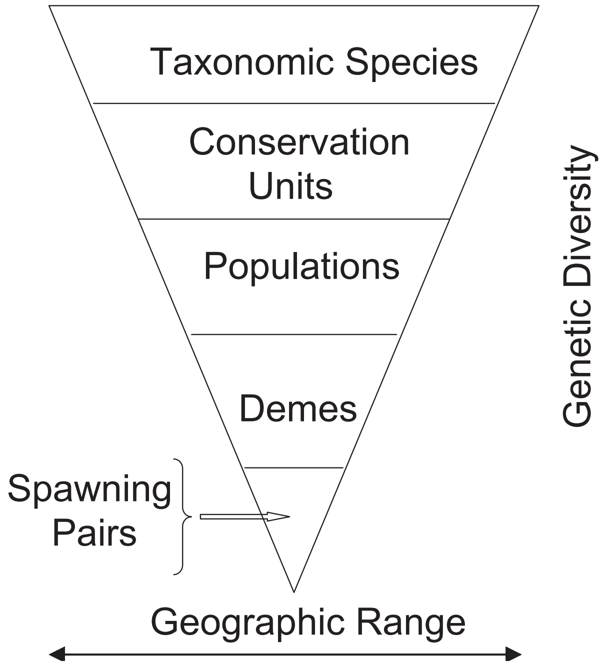

Fig. 1. Schematic illustrating the relationship between genetic diversity and geographical range for Pacific salmon (adapted from Riddell 1993).

pink salmon have two independent year lines (odd vs. even calendar years) that will constitute separate CUs.

Based on their biological status, CUs will be categorized as red, amber, or green. Status will be determined by assessing abundance (spawner escapement or proxy), distribution, diversity (genetic and life-history), and productivity (survival).

LINKING SALMON STATUS TO OCEAN STATUS

The carrying capacity of the North Pacific Ocean is an important topic to NPAFC and PICES. Salmon growth, age-at-maturity, and survival are strongly influenced by conditions experienced by salmon in the marine environment (e.g. Beamish et al. 2004; Holt and Peterman 2004) and growth can be density-dependent (e.g. Pearcy 1992). We plan to examine salmon returning to freshwater sites for evidence of changing marine conditions.

Evidence of the ocean's status can be extrapolated by monitoring the following traits in salmon when they return to fresh water:

- Size at age (i.e. marine growth)
- Age at maturity
- Return timing and changes in migratory behaviour
- Marine survival (stock recruitment)
- Oceanic distribution (based on tagging and genetic studies)
- Contaminant loads

We are in the process of designing a strategy to monitor CU status. A core programme will be established to collect the minimum agreed-upon information at all sites visited. Simulation modelling will determine the optimal annual allocation of effort needed to assess changes in CU status that may include:

- Indicator systems—comprehensive programmes usually with quantitative estimates of fishery catches plus adult and juvenile salmon abundance so that mortality can be partitioned between fresh water and marine, as well as natural and anthropogenic.
- Intensive monitoring—quantitative surveys to assess inter-annual abundance trends in CUs or CU components.

Table 1. Characteristics useful in linking salmon and ocean status[1].

Salmon species	FW winters	Ocean winters	Relative Importance of: Estuaries	Coastal areas	Open ocean	River size	Scale of MS Corr (km)
Pink	0	1 (1–3)	M	M	H	Variable	500–800
Chum	0	2-4 (1–5)	H	M	H	Variable	500–800
Sockeye	1–2 (1-4)	2-3 (1–4)	M	M	H	Variable—lakes impt	500–800?
Sockeye (sea)	0	2–4	M	M	H	Variable	500–800?
Chinook (stream)	1–2	2–4 (0–6)	H	M	H	Variable	?
Chinook (ocean)	0	3–5 (2–6)	H	H	L	Med-large	?
Coho	1–2 (0–2)	1 (0–2)	M	H	L	Small-med	500–800

[1]Characteristics include: most common (ranges) freshwater (FW) and ocean ages; relative importance (L, low; M, moderate; H, high) of estuaries, near-shore coastal, and open ocean areas; and river sizes. The scale of marine survival correlations (MS Corr) for pink, chum, and sockeye are from Pyper et al. (2005); correlations are weakest for sockeye salmon. We expect similar MS correlations for coho salmon but they may be superimposed on differential survival patterns for coastal and interior CUs.

- Extensive monitoring—similar to intensive monitoring but generally less expensive and often with broad spatial coverage in order to assess relative abundance (or presence or absence), distribution, and to monitor habitat changes.

The monitoring strategy will incorporate randomisation and replication to reduce bias and increase precision, and allow for statistical inferences to be made within and among CUs.

Known animal behaviour suggesting the relevance of estuaries, coastal areas, and the open ocean (Table 1) will help link the status of CUs to various ecosystems in the North Pacific. Chinook salmon provide an interesting example of how different life-history characteristics within a species can be used to monitor changing ocean conditions. Stream-type chinook spend one to two years in freshwater environments and rely on estuaries, but pass through coastal marine areas relatively quickly en route to oceanic feeding areas. In contrast, ocean-type chinook migrate to sea in their first year, also rely on estuaries, but show prolonged use of near-shore coastal areas. Declines in the status of ocean type chinook (or coho) salmon populations may indicate poor conditions in coastal regions close to the point of natal stream entry, while similar biological responses in stream-type chinook may reflect survival problems in the open ocean. We expect pink, chum, ocean-type chinook, and sea-type sockeye will be the most helpful for identifying changing marine conditions because of their relatively brief exposure to freshwater environments. Pink salmon will probably be the most useful of these because pinks return to spawn after only one winter at sea (quick response) and do not have multiple age-classes.

NEXT STEPS

The WSP is expected to transform the management and assessment of wild salmon in Canada (Irvine and Fraser 2007). The release of the policy is only the beginning of a process. CUs need to be confirmed and a sampling approach put in place to effectively track changes in their status. Assessments will be designed to determine the role of natural vs. anthropogenic factors (e.g. fishing) as well as which stage(s) of the salmon's life history is limiting (e.g. early marine or later) and geographic distribution (coastal shore vs. open ocean). Measurements of the CUs' changing status, combined with information regarding the biological characteristics and marine distributions of fish returning from the ocean, will aid scientists in assessing changes in marine ecosystems. Things should also work the other way—ecosystem data (including oceanographic information) will aid in the management of salmon and other species. A key ingredient for the success of this policy is collaboration. We look forward to working with scientists from other agencies and nations in the development of monitoring programmes that will help link the status of salmon with their marine ecosystems. Scientists from a variety of disciplines can benefit from the data gathered from these programmes making a good plan for archiving data essential.

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