SAG(08)5

Proposal submitted to the International Atlantic Salmon Research Board relative to furthering the knowledge on marine ecology of Atlantic salmon.

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CHANGES IN TROPHIC LEVELS OF ATLANTIC SALMON THROUGH THE MARINE PHASE OF THEIR LIFE CYCLE

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The following proposal for funding for 2008 is to analyze tissue samples from Atlantic salmon collected at index rivers in eastern Canada, as post-smolts in the northwest Atlantic, and as non-maturing 1SW salmon at West Greenland.

Costs associated with sample collection are covered by existing and new initiatives independent of this proposal.

Context

While the issue of Atlantic salmon survival is complicated by their complex life cycle requirements, there are various hypotheses regarding survival and production that may pertain to variations in Atlantic salmon abundance. One hypothesis stresses the implications of trophic structure and anthropogenic disturbances of trophic structure that have led to shortened food chains at sea. Hence, the need for investigations of variability in the trophic ecology of salmon. Trophic level can be evaluated by an examination of stomach contents over time, or through stable isotope analysis (SIA). While stomach contents provide a snapshot of recent dietary resource use, stable isotope analyses yield time integrated measures of energy assimilation since analyses are performed on body tissues built from diet assimilated over time. Consequently, SIA has been increasingly used in ecological studies as a reliable means of inferring trophic status and the impacts of anthropogenic disturbance on trophic relationships.

Atlantic salmon are considered opportunistic feeders during their freshwater and marine life-history phases. While in freshwater, juvenile salmon feed on aquatic invertebrates particularly various stages of insect groups. Differences in feeding strategies may occur between systems where parr rear extensively in lacustrine (lake) habitats versus other locations where fluvial (stream) rearing is common. During the marine phase, salmon often target prey in the upper end of the size spectrum with a preference for fish over crustaceans should both be available, but the point in the life cycle when this change happens and the relative importance of these components is poorly understood. Thus, owing to the opportunistic nature of salmon feeding habitats, the species lends itself well to studies associated with aquatic environmental conditions and food web interactions. This is particularly relevant given the variability in freshwater habitats and differences in smolt size throughout Atlantic Canada, and the potential variation in ocean climate conditions that salmon encounter when first migrating to sea over a geographic range that extends from southern Nova Scotia and New Brunswick to Labrador and into the Ungava region of Quebec.

Variability in the trophic ecology of Atlantic will be examined from analyses of stable isotope signatures of carbon and nitrogen ($\delta^{13}C$ and $\delta^{15}N$). Nitrogen stable isotope analysis provides a quantitative means to determine trophic level since nitrogen signatures from organism tissue are consistently 3 to 5‰ more enriched than dietary sources. In contrast, carbon stable isotopes are conserved up the food chain owing to the slight 0.0 to 1.0‰ enrichment occurring between prey and consumer. Because ^{13}C is conserved during trophic transfer, but varies at the base of the food web, consumer tissue stable isotope signatures will also reflect dietary source information. Various tissues have been used in the analysis of isotopic signatures, including muscle, liver, scales, and fins. Scales tend to provide a longer term perspective of trophic information while analyses of muscle and liver tissue reflect more recent energy assimilation.

We propose to sample salmon at various points in its life cycle and characterize variations and changes in trophic state from the smolt to adult life-stage. This will be accomplished by sampling smolts and adult survivors back to the river from a broad geographic range in eastern North America. Smolt information will provide information on river-specific variability in freshwater feeding strategies. Intermediate marine life-history stages will be investigated from samples obtained at West Greenland as non-maturing one-sea-winter salmon, coupled with the proposed marine research survey intended to target the early post-smolt phase.

Study design

Variability in the trophic ecology of Atlantic will be examined from analyses of stable isotope signatures of carbon and nitrogen ($\delta^{13}C$ and $\delta^{15}N$) with comparisons among populations at the freshwater-smolt stage, as well as between life-history stages from post-smolts caught at sea, non-maturing 1SW salmon feeding at West Greenland, and with adults that return to respective rivers in the following year.

We propose to analyze isotope signatures from muscle, liver, scales and adipose fin tissue. In situations where lethal sampling of salmon is not an option (e.g., catch-and-release angling fisheries, populations at low abundance), scales and adipose fins provide non-lethal alternatives. As noted earlier, this approach will yield information on ontogenetic differences in isotope signatures across life-history stages (smolt, post-smolt, adult) across a broad geographic area.

Samples from West Greenland and from the proposed research cruise will be obtained on an opportunistic basis with a target of approximately 150 specimens from each but with potentially more samples from the marine research cruise should they be available; this, however, would increase the estimated costs of analysis. The potential river sampling locations and the respective tissues identified for stable isotope analyses are identified in Table 1.

To complement salmon trophic information, isotope analyses will also be carried out on a subset of other species that may be captured in the pelagic trawl, or obtained from stomach contents of salmon at sea. These data will provide insight into key dietary items of the food web structure within which salmon operate. Thus, five replicate samples of each of the key prey types within the size range consumed would be desirable.

Table 1. *Location, life stage and tissues to be sampled from Atlantic salmon to examine trophic ecology.*

							Returning adults			
			From Smolts				1SW salmon		2SW salmon	
SFA/Zone	River	Tributary	Muscle	Liver	Fin	Scales	Fin	Scales	Fin	Scales
23	Nashwaak		X	X	X	X	X	X	X	X
21	LaHave		X	X	X	X	X	X	X	X
18	Margaree		X	X	X	X	X	X	X	X
16	Miramichi	Southwest	X	X	X	X	X	X	X	X
		Northwest	X	X	X	X	X	X	X	X
15	Restigouche	Kedgwick	X	X	X	X	X	X	X	X
		Upsalquitch	X	X	X	X	X	X		
Q2	St-Jean		X	X	X	X	X	X	X	X
Q7	De la Trinite		X	X	X	X	X	X	X	X
11	Conne		X	X	X	X	X	X		
9	Rocky		X	X	X	X	X	X		
4	Campbellton		X	X	X	X	X	X		
4	Exploits		X	X	X	X	X	X		
14A	Western Arm		X	X	X	X	X	X		
2	Sand Hill		X	X	X	X	X	X	X	X
			Post-smolt and West Greenland							
Post-smolt			X	X	X	X				
West Greenland			X	X	X	X				

Samples will be collected over three years with the objective of tracking changes in trophic ecology of salmon through the marine phase (Table 2). In addition, annual variation in trophic state among 1SW maturing, 1SW non-maturing and 2SW salmon will be examined by sampling these stages even if some of the data on smolts or early post-smolt stages are not available. The samples from West Greenland will also provide inter-continental comparisons of trophic ecology for that life stage.

Table 2. *Schedule of samples to be collected by life stage.*

	2008					2009					2010				
	May	June	July	August	September	May	June	July	August	September	May	June	July	August	September
Smolt	X	X				X	X								
Post-smolt				X					X						
Marine prey (post-smolt)				X					X						
1SW salmon							X	X				X	X		
1SW non-maturing (WG)				X	X				X	X				X	X
Marine prey (WG)				X	X				X	X				X	X
2SW salmon							X	X				X	X		

Estimated cost of analysis over the next three years (2008 to 2010)

As the number of life stages sampled varies with the year, the cost of analysis also varies. Stable isotope analysis for C and N costs $10 per tissue sample. For 2008, the proposed cost of analysis is $39,000 (Cdn).

Life stage	Number of locations	Tissues	Number of samples per tissue	Total
Smolt	15 index rivers	Muscle, liver, scales, adipose	30	$18,000
Post-smolt	Labrador Sea	Muscle, liver, scales, adipose	150	$6,000
Marine prey	Labrador Sea, Two locations	20 prey item types	5	$2,000
1SW non-maturing (WG)	West Greenland	Muscle, liver, scales, adipose	150	$6,000
Marine prey	West Greenland	20 prey item types	5	$2,000
Labour for laboratory preparations				$5,000
Funding for analysis for 2008				**$39,000**

Smolt	15 index rivers	Muscle, liver, scales, adipose	30	$18,000
Post-smolt	Labrador Sea	Muscle, liver, scales, adipose	150	$6,000
Marine prey	Labrador Sea, Two locations	20 prey item types	5	$2,000
1SW salmon	15 index rivers	Scales, adipose	30	$9,000
1SW non-maturing (WG)	West Greenland	Muscle, liver, scales, adipose	150	$6,000
Marine prey	West Greenland	20 prey item types	5	$2,000
2SW salmon	9 index rivers	Scales, adipose	30	$5,400
Labour for laboratory preparations				$7,500
Funding for analysis for 2009				**$55,900**

1SW salmon	15 index rivers	Scales, adipose	30	$9,000
1SW non-maturing (WG)	West Greenland	Muscle, liver, scales, adipose	150	$6,000
Marine prey	West Greenland	20 prey item types	5	$2,000
2SW salmon	9 index rivers	Scales, adipose	30	$5,400
Labour for laboratory preparations				$4,000
Funding for analysis for 2010				**$26,400**

Timelines for the tissue collections and analysis

<u>For 2008</u>

The tissue collections from smolts from the index rivers began in May 2008 and will be completed by the end of June 2008. The post-smolt survey for the Labrador Sea is anticipated for August 2008 with tissue collection occurring on the vessel. The West Greenland samples would be collected in August and September and be available for analysis by the end of October 2008.

All the laboratory analyses would be conducted between September 2008 to February 2009 with preliminary analyses and interpretation available for the ICES Working Group meeting in April 2009 and the NASCO meeting of June 2009.

Timelines for other years would follow a similar schedule.

Coordination, data analysis and interpretation

Tissue collection from the index rivers and for post-smolts is being coordinated by Gerald Chaput (DFO Gulf Region).
Tissue collection and prey items from West Greenland are coordinated by Dr. Tim Sheehan (NMFS, NOAA, US).
Isotope analyses will be coordinated by Dr. Michael Power and conducted at the Environmental Isotope Laboratory, University of Waterloo (Canada).
Data analysis and interpretation will be lead by Brian Dempson (DFO NL, Canada) and Dr. Michael Power (U. of Waterloo, Canada).