Optimizing the production of Chinook salmon in the Strait of Georgia as the ecosystem changes.

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Changes in the environment of the Strait of Georgia are affecting the productivity of hatchery and wild Chinook salmon. To improve of our understanding of the factors regulating this change in productivity we are focussing specifically on the marine phase of the Cowichan River Chinook salmon. However, our analysis also includes information on other Chinook salmon stocks throughout the strait. As part of the study, we also are collaborating with Dave Beauchamp (University of Washington) and his colleagues in Puget Sound to compare bioenergetic changes in the Strait of Georgia with this neighbouring ecosystem.

The program was initiated in April 2008 and a second year of funding was requested and approved for 2009/2010. However, due to the economic downturn in the economy, the second year of funding was delayed. To provide continuity to the program, the agreement for the original funding was extended through 2009/2010 and alternate funding was secured through DFO in to assist with the project. This report summarizes the work conducted to date on this program. Some analysis has been delayed due to changes in the funding structure of the program, however, all relevant samples were collected in 2009 and analysis will be completed in 2010.

Field sampling was conducted in three key marine habitats for Cowichan River Chinook salmon; Cowichan River estuary (beach seine sampling), Gulf Islands near shore areas (purse seine survey) and mid-water (mid-water trawl surveys in Gulf Islands and Strait of Georgia). With this sampling design we were able to successfully sample Cowichan River Chinook salmon throughout their early marine residency from ocean entry in April/May to November. The use of coded-wire tags and DNA analysis provided retrospective information on the distribution of Cowichan River Chinook salmon as well as other Chinook salmon stocks in our samples.

A. **Beach seine surveys – Cowichan estuary**.

The beach seine surveys in the Cowichan River estuary were conducted in 2008 and 2009. Sampling was conducted with two vessels fishing concurrently in the mouth of the river and along the north or south sides of Cowichan Bay (Figure 1). Although Chinook salmon were the focus of the surveys, all salmon species were sampled and non-salmon species were enumerated and measured.

Figure 1. General area of beach seine sampling (in red) in Cowichan Bay in 2008 and 2009. Sample locations are indicated in red.

Sampling in both years followed similar protocol, however, the sampling effort in 2009 was reduced to once per week due to larger catches of Chinook salmon (Table 1). Overall, catch of Chinook salmon per set between May and early June was about 2.2 times greater in 2009 than 2008. The larger catches of Chinook salmon in 2009 are likely a reflection of increased

hatchery releases from approximately 460,000 Chinook salmon smolts in 2008 to 1.6 million smolts in 2009. In both years the majority of the Chinook salmon was caught along the northern side of Cowichan Bay and in the north fork of the river.

In 2008, 100% of the hatchery smolts were marked with a clipped adipose fin and coded wire tags (CWT). In 2009 only 42% of the hatchery release was marked. In both years most of the hatchery releases occurred in the third week of May with smaller early releases (2008 – mid April, 2009 – early May) and a later seapen release in both years.

Table 1. Catch numbers of salmon and most frequent non-salmon species in beach seine survey in Cowichan Bay in 2008 and 2009.

Date	# Sets	Chinook	Coho	Chum	Pink	Steelhead	Sculpin	Stickleback
April 8, 2008	7	1		54			>200	
April 18, 2008	4	5		7			3	
May 6, 2008	10	10	1	1272	23		295	1621
May 8, 2008	9	13	5	2024	2	17	691	9
May 13, 2008	10	3	1	>2000			168	53
May 15, 2008	7	2		163			>165	
May 20, 2008	8	3	3	204	10		245	8
May 22, 2008	8	7	17	>400		1	~450	present
May 27, 2008	7	13	6	47			160	
May 29, 2008	8	30	2	34			274	1
June 5, 2008	11	493	21	76	11		309	55
Total 2008	**89**	**580**	**56**	**>5000**	**46**	**18**	**>2500**	**>1700**
May 7, 2009	6	71	3	67			49	46
May 14, 2009	9	235	3	42			81	7
May 21, 2009	7	357	4	47			310	1301
May 26, 2009	7	111	7	55			67	72
June 2, 2009	8	43	2	17			141	109
June 11, 2009	8	14	0	41			95	50
Total 2009	**45**	**831**	**19**	**269**	**0**	**0**	**743**	**1585**

The high tagging percentage (100%) in 2008 allowed us to determine that the percent contribution of hatchery fish in our samples increased following releases from the hatchery (Figure 2). This calculation was more complicated in 2009 due to the reduced tagging rate. The percent of adipose clipped Chinook salmon in our catch in 2009 averaged 47% and ranged from 65% - 33% from May 7 to May 26 and from 0-9% from June 2 to 11, 2009. Applying a marking percent of 42% we expect that the majority of the fish caught in May were of hatchery origin, however, this cannot be confirmed without analysis of the otolith microstructure.

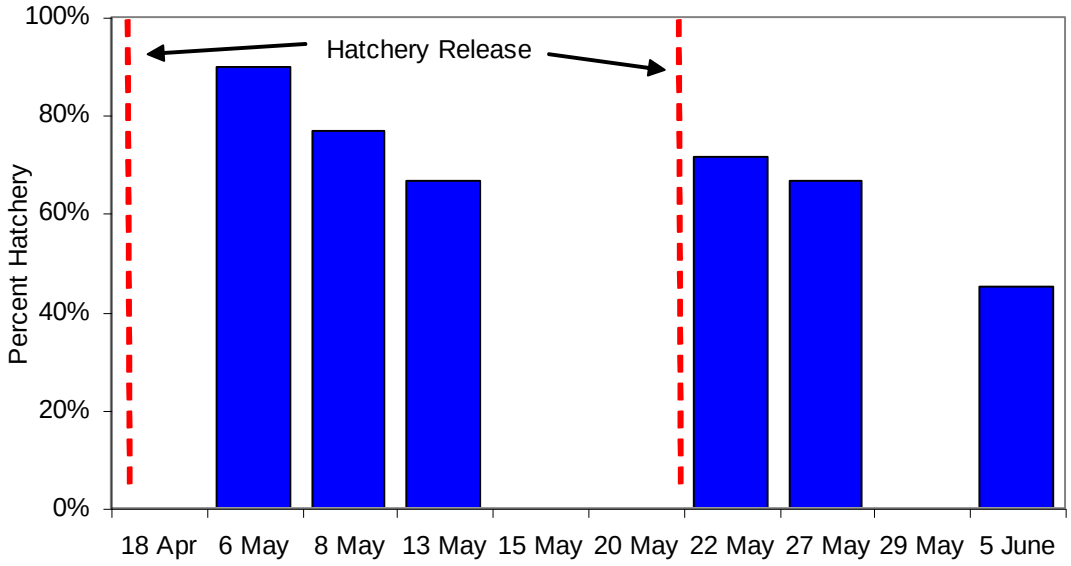

Figure 2. Proportion of hatchery reared Chinook salmon caught in beach seine survey in Cowichan Bay April – June, 2008. Red dashed lines indicate release times from the hatchery.

The average size of Chinook salmon captured in the beach seine survey was smaller in 2009 than in 2008 (Table 2). In both years the Chinook salmon that were marked were larger than the un-marked fish (Table 2). It must be remembered that without the otolith analysis the unmarked group of Chinook salmon in 2009 contains both hatchery and wild Chinook salmon.

Catches of coho salmon were lower than Chinook salmon catches in both years (Table 1). In 2008 the coho salmon were longer than in 2009 (Table 2). Chum salmon were the dominant salmon in our catches in 2008 but not in 2009 (Table 1). Their average length was similar in both years (Table 2).

Table 2. Average fork lengths of Chinook, coho and chum salmon captured by beach seine in Cowichan Bay, 2009 and 2008

Date	Chinook (no adipose fin clip)		Chinook (adipose fin clip)		Coho		Chum	
	2008	2009	*2008*	2009	*2008*	2009	*2008*	2009
May 7	*59*	66	*83*	79	*136*	64	*49*	44
May 14	*69*	75	*80*	79	*97*	100	*46*	44
May 21	*68*	71	*93*	80	*94*	94	*53*	63
May 26	*82*	68	*98*	75	*94*	103	*59*	56
June 2	*64*	70	-	84	*145*	87	*62*	55
June 11	*76*	71	*88*	-	*98*	-	*61*	67
Average	***71***	**70**	***88***	**79**	***104***	**93**	***51***	**52**

The most common by-catch species in the beach seine survey in both years were stickleback, staghorn sculpins, herring, shiner perch and sandlance. In addition small numbers of starry flounder, gunnels, sandabs, bay pipefish and juvenile lingcod/greenlings were observed.

B. Gulf Islands Purse Seine surveys

Purse seine surveys were conducted June 20-27, 2008 and June 1-5, 2009 to examine the distribution and size of juvenile Cowichan River Chinook salmon and other Chinook salmon stocks in the Gulf Islands area. The survey area was divided into nine sub-areas for preliminary analysis and discussion (Figure 3). The catch and catch per unit effort (CPUE) of salmon and herring in the purse seine survey is summarized in Table 3.

In both years, the highest catches of Chinook salmon were in Cowichan Bay. The CPUE was lower in 2009 than in 2008 even though hatchery releases were approximately three times higher. This, coupled with our exceptional catches in the beach seine survey at the same time, suggests that the Chinook salmon may have still been in the shallower estuary waters at the time of our purse seine survey in 2009 (June 1-5).

DNA analysis on Chinook caught in 2008 indicated that all Chinook salmon caught in Cowichan Bay had originated from the Cowichan River. Based on CWT recoveries, 26% of these fish originated from the hatchery. Analysis has not been completed for 2009. However, based on the DNA results from 2008 and on the fact that all 44 of the CWT's recovered in this area in 2009 originated from the Cowichan River hatchery, it is likely that all of the Chinook salmon caught within Cowichan Bay in 2009 were from the Cowichan River. The 44 CWT's

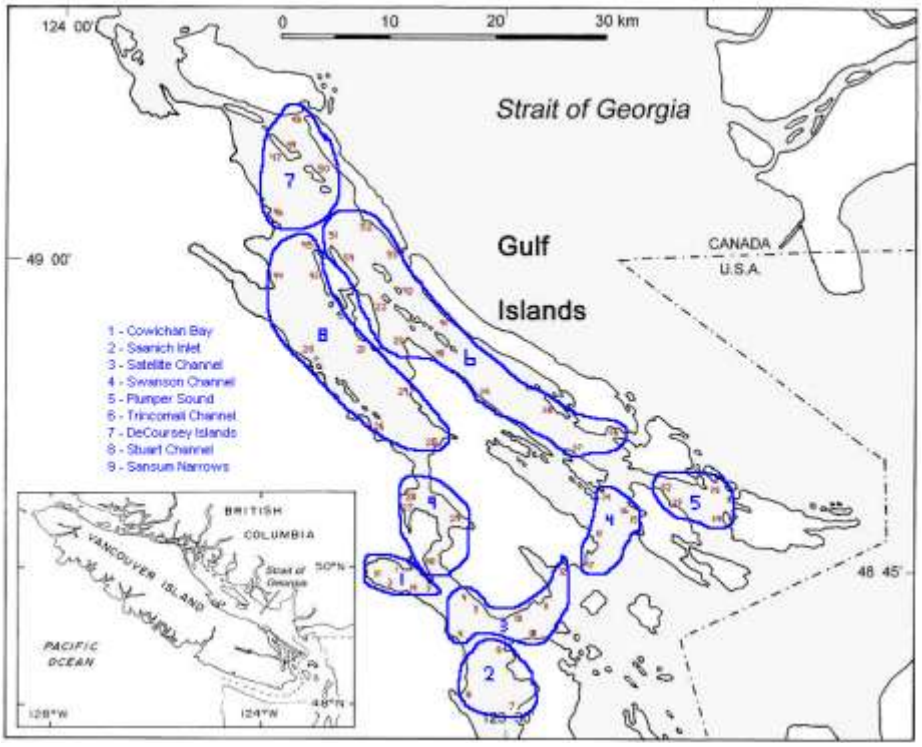

Figure 3. Locations of purse seine set locations in Gulf Islands, June 1-5, 2009. Set locations were similar during June 20-27, 2008 survey.

recovered represent 42% (marking rate) of the hatchery fish in our sample. This would indicate that the 91 Chinook captured in the Cowichan Bay area in June 2009 were most likely hatchery fish. This increase in hatchery percent from 2008 reflects the increased release of hatchery fish released in 2009, but we do not know if the increase hatchery releases also influenced wild Chinook mortality or if the timing of the wild migration was earlier or later and therefore wild fish were missed by our survey. Results from DNA and otolith analysis of Chinook salmon collected from our beach seine survey and purse seine survey in 2009 will help clarify this.

In 2008 we estimated that the early marine survival (ocean entry to September) of hatchery reared Chinook salmon from the Cowichan River (1.5%) was lower than the survival of the wild Chinook salmon (10%). This calculation was based on the proportion of hatchery and wild fish observed in the purse seine survey and later in the trawl survey. This calculation has not been completed for 2009 because we have not yet received the information from the DNA analysis. The reduced tagging proportion of hatchery fish (42%) will reduce the certainty of our estimates, however, additional analysis of otolith microstructure may assist in separating hatchery and wild Chinook salmon in our catch.

Table 3. Catch and CPUE of salmon and herring in the purse seine survey in the Gulf Islands, June 20-27, 2008 and June 1-5, 2009

		Chinook		Coho		Sockeye		Chum		Pink		Herring (1+)		Herring (YOY)	
2008	**# sets**	**catch**	**CPUE**	**catch**	**CPUE**	**catch**	**catch**	**catch**	**CPUE**	**catch**	**CPUE**	**catch**	**CPUE**	**catch**	**CPUE**
1 – Cowichan Bay	3	104	34.7	1	0.3	14	0	483	161.0	138	46.0	0	0	0	0
2 – Saanich Inlet	2	0	0	0	0	1	0	10	5.0	2	1.0	0	0	2050	1025.0
3 – Satellite Channel	12	13	1.1	2	0.2	50	37	547	45.6	531	44.3	37	3.1	3	0.3
4 – Swanson Channel	6	0	0	0	0	67	1	193	35.2	409	68.2	1	0.2	1	0.2
5 – Plumper Sound	5	4	0.8	0	0	5	3	197	39.4	322	64.4	3	0.6	0	0
6 – Trincomali Channel	16	5	0.3	4	0.3	30	5	157	9.8	86	5.4	5	0.3	12018	751.1
7 – DeCoursey Islands	7	1	0.1	0	0	17	0	114	16.3	58	8.3	0	0	1	0.1
8 – Stuart Channel	6	3	0.5	0	0	0	0	24	4.0	0	0	0	0	0	0
9 – Sansum Narrows	7	44	6.3	1	0.1	4	0	150	21.4	189	27.0	0	0	13500	1929.0
Total 2008	***64***	***174***	***2.7***	***8***	***0.1***	***188***	***46***	***1875***	***29.6***	***1735***	***27.1***	***46***	***0.7***	***27573***	***430.8***
2009	**# sets**	**catch**	**CPUE**	**catch**	**CPUE**	**catch**	**CPUE**	**catch**	**CPUE**	**catch**	**CPUE**	**catch**	**CPUE**		
1 – Cowichan Bay	5	91	18.2	15	3.0	4	0.8	51	10.2			4,800	960.0		
2 – Saanich Inlet	3	8	2.7	5	1.7	0	0	0	0			25	8.3		
3 – Satellite Channel	7	41	5.9	14	2.0	118	16.9	1127	161.0			260	37.1		
4 – Swanson Channel	5	0	0	2	0.4	18	3.6	471	94.2			1,026	205.2		
5 – Plumper Sound	4	1	0.3	3	0.8	3	0.8	88	22.0			500	125.0		
6 – Trincomali Channel	13	8	0.6	11	0.8	28	2.2	869	66.8			2,626	202.0		
7 – DeCoursey Islands	5	2	0.4	3	0.6	10	2.0	138	27.6			0	0		
8 – Stuart Channel	8	20	2.5	5	0.6	7	0.9	714	89.3			1,000	125.0		
9 – Sansum Narrows	4	16	4.0	4	1.0	48	12.0	229	57.3			28	7.0		
Total 2009	***54***	***187***	***3.5***	***62***	***1.1***	***236***	***4.4***	***3687***	***68.3***			***10,265***	***190.1***		

Other salmon species were also collected in this purse seine surveys. Chum salmon was the most abundant in both years although the CPUE in 2009 was just over double the CPUE in 2008 (Table 3). In both years chum salmon were caught throughout the Gulf Islands with the largest catches in sets along the south end of Saltspring Island. The CPUE of sockeye was greater in 2009 than in 2008 however, the distribution was similar in both years and similar to the distribution of chum salmon (Table 3). Catches of coho salmon were higher in 2009 than in 2008 although catches were relatively low in both years (Table 3). The majority of pink salmon in the Strait of Georgia originate from the Fraser River and only enter the ocean in even numbered years. Therefore it is not surprising that catch numbers were high in 2008 (Table 3). In 2009 there were no pink salmon caught in either the beach seine or purse seine survey. There was a release of pink salmon from net pens in Cowichan Bay in both years but in 2009 this release occurred after our beach seine survey.

Pacific herring were caught in the purse seine survey in both 2008 and 2009 but the age composition between the two years was different. In 2009 we caught no young of year (YOY) herring whereas they were abundant in 2008. This is likely because of the early timing of the survey in 2009 along with the herring spawn in the Strait of Georgia occurring several weeks later than normal in 2009. Other species observed in the catch in the purse seine survey included stickleback, anchovy, juvenile wolf eel, sandlance, steelhead trout, adult Chinook salmon, pollock and bay pipefish.

Table 4. Average lengths of salmon captured in the Gulf Islands purse seine survey, June 2009

Area	Chinook (no adipose fin clip)	Chinook (adipose fin clip)	Coho	Sockeye	Chum
1 – Cowichan Bay	92	91	121	95	77
2 – Saanich Inlet	95	87	122	-	-
3 – Satellite Channel	95	94	115	103	76
4 – Swanson Channel	116	-	111	97	77
5 – Plumper Sound	-	152	112	108	85
6 – Trincomali Channel	108	129	127	99	75
7 – DeCoursy Islands	111	-	158	95	77
8 – Stuart Channel	103	88	118	96	73
9 – Sansum Narrows	91	90	130	102	81
2008 Average	***99***	***123***	***143***	***109***	***87***
2009 Average	***95***	***93***	***122***	***100***	***76***

C. Ricker Trawl Surveys

Trawl surveys were conducted in the Gulf Islands and Strait of Georgia in both 2008 and 2009. In 2009 sampling was conducted in the Gulf Islands in June, July, September, October and November and in the Strait of Georgia in June/July, September and November (Table 5). Catch levels of Chinook salmon in both years indicate that both the Gulf Islands and the Strait of Georgia are key rearing areas for juvenile Chinook salmon through to September (Table 5). Although Chinook salmon are still present in the Gulf Islands and in the Strait of Georgia in November the numbers are greatly reduced (Table 5).

Table 5. Total number of Chinook salmon and number of Chinook salmon with CWT's caught in trawl surveys in 2009.

Date	Area	# sets	# Chinook salmon	# CWT's
June 24-26	Gulf Islands	20	2645	363
June 26- July 7	Strait of Georgia	83	2036	83
July 17-19	Gulf Islands	23	1669	228
September 11-13	Gulf Islands	24	906	97
September 15-25	Strait of Georgia	87	1181	18
October 2-4	Gulf Islands	24	1068	93
November 17-19	Gulf Islands	23	77	7
November 19, 21	Strait of Georgia	14	60	5

In 2009, the abundance of juvenile Chinook salmon in the Gulf islands was approximately 1.6 million in July and 0.65 million in September. The relative catch of other salmon species in the Gulf Islands was similar to the numbers observed in the purse seine survey with chum salmon being the dominant species (Table 6).

Preliminary diet analysis indicates that there are no major differences in diet items or proportions in juvenile Chinook salmon caught in the Strait of Georgia and Gulf Islands regions. In both areas, herring were the dominant diet item, comprising 71% of the total volume. Amphipods, decapods and krill contributed 13, 12 and 2% to the diet respectively.

Results from DNA analysis of tissue samples collected in the purse seine survey and trawl survey in 2008 suggest that Cowichan River Chinook salmon remain in the Gulf Island region through to September or November (Figure 4). In the midwater trawl survey in June 2009, only 19% of the Chinook salmon captured were from the Cowichan River, 64% of which were of hatchery origin (Figure 4B). However by July, the proportion of Cowichan River Chinook

Table 6. Summary of juvenile salmon data from June 24-26, 2009 midwater trawl survey in the Gulf Islands.

	Catch	CPUE (catch/hr)	Abundance	Length (mm)	Condition Factor
Coho	624	62.4	375,418	156.9	1.17
Chinook	2,645	264.5	1,600,978	114.9	1.17
Chum	3,708	412.0	2,243,428	94.9	0.89
Pink	5	0.6	3,028	124.4	-
Sockeye	131	14.5	75,689	108.0	0.92

salmon in the trawl survey was similar to that seen in the purse seine survey (Figure 4C), suggesting that juvenile Chinook salmon from the Cowichan River may be nearshore for several weeks before moving into deeper waters. The proportion of Chinook salmon from the Cowichan River in the trawl surveys in September was greatly reduced (Figure 4D), as was the proportion of Cowichan River Chinook salmon that were of hatchery origin. This suggests differential early marine survival of hatchery and wild Chinook salmon from the Cowichan River. This trend continues into October and November (Figure 4E,F).

In 2009, preliminary results from CWT analysis suggest a similar pattern. The majority (87%) of the CWT's recovered in the Gulf Islands in September 2009 were from the Cowichan River. The remaining 13% were a combination of Big Qualicum, Grovers Creek (Puget Sound) and unidentified tags. Similar results were observed for the early October survey in the Gulf Islands with 78% originating from the Cowichan River and approximately 14% originating from Puget Sound and Boundary Bay. There is some evidence of a few Cowichan River Chinook salmon moving into the Strait of Georgia in July and about 5% of the tags recovered in the Strait of Georgia in September 2009 originated from the Cowichan River. More detailed information on the distribution of this stock in 2009 will be available from the DNA.

DNA analysis from 2008 provides information on variation in size of catch between July and September and the Gulf Islands and Strait of Georgia. The average length difference of juvenile Chinook salmon between July and September in the Gulf Islands was greater than the difference observed for fish caught in the Strait of Georgia. However, DNA analysis

indicated that the apparent lack of growth between July and September in the Strait of Georgia is due to a strong influx of Chinook salmon from the South Thompson River that migrate to the ocean as fry and enter the Strait of Georgia around mid-July (Figure 5). Thus, the length frequencies observed in the July survey are for different stocks than those observed in September.

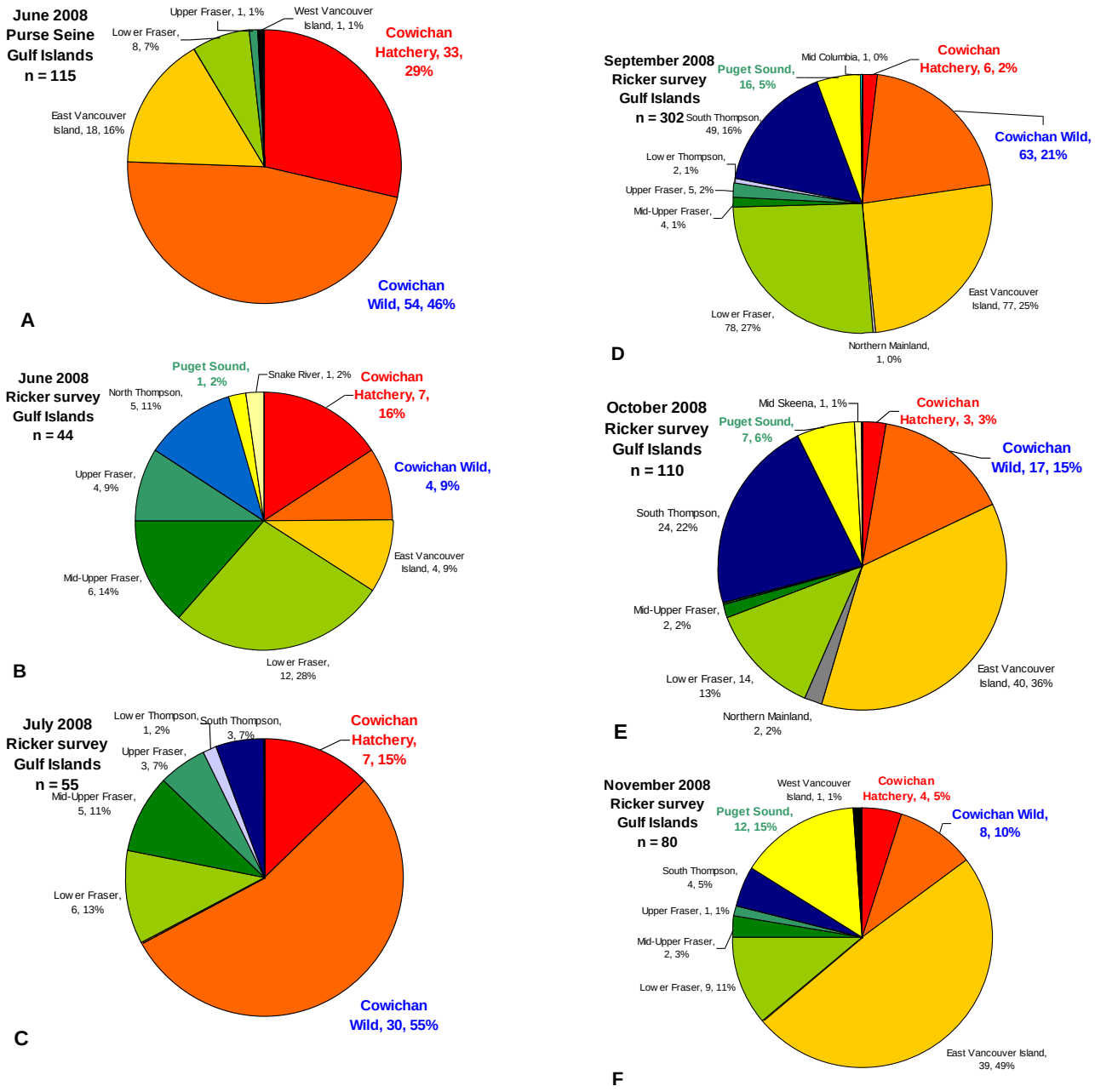

Figure 4. Results of DNA analysis from purse seine and midwater trawl surveys in the Gulf Islands in 2008. A) Purse seine survey, June 20-27; B) Trawl survey, June 24-26; C) Trawl survey, July 16-17; D) Trawl survey, September 10-12; E) Trawl survey, October 3-4; and F) Trawl survey, November 17-19

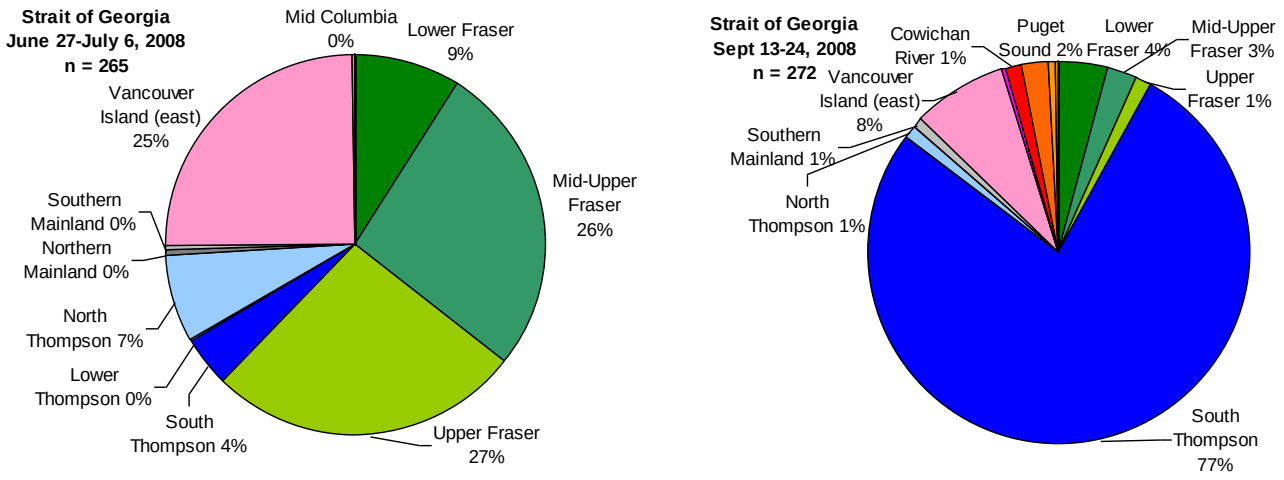

Figure 5. Results of DNA analysis of Chinook salmon in the Strait of Georgia in July and September 2008.

This initial research on the early marine period of Cowichan River Chinook salmon has demonstrated the importance of the Gulf Island region as an important rearing area through the summer months for this stock as well as other Strait of Georgia Chinook stocks. Initial work has suggested that the early marine mortality between ocean entry and September of the Cowichan River Chinook salmon is extremely high and identifying where and why this mortality is occurring will be critical to managing this stock and will be the focus of the work in 2010.