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Structural patterns in the distribution of ocean- and stream-type juvenile chinook salmon populations in the Strait of Georgia in 2010 during the critical early marine period

By

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Abstract

There is increasing evidence that brood year strength of chinook salmon is mostly determined in the first few months in the ocean, particularly in a stressful environment. During this period in the Strait of Georgia, some chinook salmon populations have a distinct and persistent behaviour that relates to ocean entry times or concentrates their distributions in areas or at particular depths. Populations with both ocean- and stream-type life histories remain within the Strait of Georgia for three to four months, depending on their ocean entry times. These distinct and persistent behaviours during the critical early marine period indicate that conditions in the Strait of Georgia have a major impact on the productivity of the various populations. Populations of both stream- and ocean-type fish remained in the Strait of Georgia through to mid September, indicating that conditions within the Strait of Georgia would have a major impact on growth and survival. The major structural change in the population composition between July and September and the observation that the late ocean entry populations have a higher productivity than populations with an earlier ocean entry is evidence that recent changes in the environment of the Strait of Georgia are affecting the combined productivity of all populations. Other studies have shown that the environment within the Strait of Georgia has been changing and the changes appear to be long-term trends. Thus, it is advisable that the management of chinook salmon recognize the differences among populations within the early marine period as these differences may explain the reason for poor or good survival. Populations with good survival have the resilience needed to adapt to future environmental changes in the Strait of Georgia.

Introduction

In 1998 we began a study of the factors that affected the survival of juvenile Pacific salmon (*Oncorhynchus* spp.) in the early marine period in the Strait of Georgia. Juvenile Pacific salmon were captured with a modified mid-water trawl that was fished in a standardized survey (Beamish et al. 2000, Sweeting et al. 2003). Beginning in 2008, we were able to use DNA population identification (Beacham et al. 2006) to identify the various populations of chinook salmon (*O. tshawytscha*). In 2010, we were able to add two purse seine surveys to the standardized trawl survey as well as adding a third trawl survey in early June.

It is generally accepted that chinook salmon have two life history types that are identified as ocean and stream types in Canada and sub-yearlings and yearlings in the United States (Healey 1991). The stream type or yearlings spend one year in fresh water before entering the ocean and the ocean type or sub-yearlings enter the ocean in their first year after hatching. However, there are other life history types such as late ocean entry, ocean-type chinook salmon that are also distinct. In this report, we compare the resident behaviour and distribution of populations with ocean- and stream-type life histories in the early marine period.

Methods

In this report, we will refer to a genetically distinct aggregate of chinook salmon as a population. The trawl used in 2010 and the method of fishing are described in Beamish et al. (2000) and Sweeting et al. (2003). The modified mid-water trawl net had an opening of approximately 30 m wide and 15 m deep. The trawl was fished at a speed that was sufficient to capture all sizes of Pacific salmon in the Strait of Georgia. The depth of each set was determined to ensure that a percentage of sets fished all 15 m strata from the surface to a head rope depth of 60 m. Most fishing was in the top 30 m because many juvenile Pacific salmon were at this depth. However, juvenile chinook and coho salmon were deeper, resulting in a smaller percentage of sets with head-rope depths of 30, 45 and 60 m. Catches are the number of fish in a 30-minute set unless standardized to one hour which is identified as catch per unit effort (CPUE). Average CPUE is the number of fish captured at the specified depths divided by the number of hours fished. Average catch is the sum of the catch for each set divided by the number of sets. All lengths are fork lengths. The purse seine surveys from June 8-12 and August 3-17 used a seine net that was 285 m long and 9 m deep with a 6 mm knotless bunt. Survey areas in the purse seine survey were generally closer to shore than the trawl surveys. Sites for the purse seine survey were selected to ensure that strong winds and strong currents did not collapse the net. All surveys are identified in the text by month. If a survey extended over two months, the month that has the most survey days is used. Population-specific identifications using DNA followed the procedures in Beacham et al. (2006). More fish were sampled for DNA than could be analyzed. Samples for DNA analysis from the trawl survey were selected from areas around the Strait of Georgia. Once samples were selected, the individual fish samples were randomly chosen. Samples for DNA analysis from the purse seine surveys were taken from all sets. If the catch exceeded 30 fish, only 30 fish were sampled. All fish from a particular area were analyzed but not all areas were analyzed. Scales were obtained from samples collected in the purse seine surveys using standard procedures for collecting, storing and pressing scales. The spacing of circuli and the presence of a freshwater annulus were used to distinguish ocean- and stream-type life histories. Each scale was examined independently and simultaneously by two individuals with experience in ageing salmon scales. Any differences in interpretation were resolved and the resolved determinations recorded.

Results and Discussion

Catch per unit effort (CPUE) in the trawl surveys

In the June survey, 13 of the 69 sets were deeper than the surface 15 m (Figure 1). The combined CPUE at the 15-29 m, 30-44 m and 45-59 m depths was approximately 1.2 times the CPUE at the surface, indicating that slightly more than one half of all juvenile chinook salmon were below the surface 15 m (Figure 1). In the July survey, the combined CPUE in the two strata below the surface was 3.2 times the CPUE at the surface (Figure 1). The CPUE at the 45-59 m depth was about 2/3 of the CPUE at the surface 15 m. Very few juveniles were captured below 60 m. Only about 1/5 of the standardized catch occurred in the surface 15 m. In the September survey, the average CPUE in the surface

15 m was larger than the other depths, but the abundance of all juvenile chinook salmon below the surface 15 m, as indicated by CPUE, was 1.8 times the abundance at the surface (Figure 1). Thus, the depth distribution changed from being mostly below the surface 15 m in July to a distribution more similar to June when the largest abundance was at the surface. If most juvenile chinook salmon enter the Strait of Georgia about mid May, it appears that in June, juvenile chinook salmon are closer to the surface. The increase in the abundance of the standardized catch in the surface 15 m in September compared to July was a result of the entry of South Thompson River populations. The standardized catch deeper than 59 m indicated that juvenile chinook salmon were in relatively deep water in September, representing approximately 1/5 of the total abundance.

Size

In the June survey, the average length of the juvenile chinook salmon was the largest in the water deeper than 29 m (Figure 2). There was no difference in the mean lengths between the 30-44 m and 45-59 m strata. In the July survey, the average size was similar in the top 30 m. Fish in the 30-44 m stratum were significantly larger than at the surface (ANOVA, $P \leq 0.05$) as were fish in the 45-59 m stratum. The fish in the 45-59 m stratum were much larger than those in the top 44 m (Figure 2). However, the CPUE at depths greater than 44 m was relatively small, indicating that most juvenile chinook salmon were in the top 44 m in July and were smaller. In the September survey, the mean length of the juveniles increased for all depth strata below 29 m. The mean length for all strata deeper than the surface 29 m was significantly larger than those at the surface (ANOVA, $P \leq 0.05$). The CPUE for the depth strata below 29 m in September indicated that there were about 40% of all juveniles at these depths.

Scales

Scales from 69 fish caught in the June purse seine survey were examined for the presence of a freshwater annulus which would indicate that the fish spent one winter in fresh water and was a stream type. Two readers read each scale independently and resolved interpretations that differed. Interpreting the scales was not routine because there were not large differences in the number of circuli between the two life history types. There was an average of 12.7 circuli on the stream type (n = 28) and 11.0 on the ocean type (n = 41). Using these determinations, the scale classification agreed with the genetic baseline categorization 88.4% of the time. Although this is a relatively small sample, we concluded from these determinations that the life history categorization in the genetic baseline is an acceptable categorization of life history type, at least until more scales are examined. However, when we examined 111 scales from the August purse seine sample, we did not find as good agreement with the genetic based life history determination. In this sample there were 20 stream-type fish of which there was agreement on only one. There were 91 ocean-type fish and we agreed on all.

Our general conclusion is that the life history categorization in the genetic data base provides a useable categorization of life history type. However, the accuracy of the determination needs to be assessed. This assessment includes an evaluation of the accuracy and precision of the scale-based life history determination.

Ocean and stream life history type

Individual populations are aggregated into groups with specific colours. The population composition within each colour is identified in Table 1. The individual populations are also compared according to their life history type and according to the catch location.

In the June trawl survey, most (81%) of the fish in the surface 15 m were considered to be stream-type fish with about 15% ocean type and a small percentage (4%) that were of unknown life history type (Figure 3). The percentage of ocean type decreased with depth. The larger fish found in deeper water were less abundant than in the surface 29 m (Figure 1). The stream-type fish sampled for DNA and used to determine the population composition had average lengths at the various depths that were more similar than for the total sample in Figure 2 (Table 2). In fact, the largest fish were at the surface. The larger size of the stream-type fish clearly separated them from the ocean-type fish. In the June 10-21 purse seine survey the percentage of stream- and ocean-type fish in the surface waters was almost the opposite to the June trawl sample, with 79% ocean type and 19% stream type (Figure 4). There were six populations with an ocean-type life history in the trawl catches in June and 31 populations with an ocean-type life history in the June purse seine catches. Fish from the larger populations were found in the catches of both gear types, but individuals from many of the smaller populations were not in the samples selected from the trawl catches for DNA population analysis. About one half of the catch in the purse seine was from the populations from the east side of Vancouver Island. It is apparent that there are differences in the composition of the life history types between the areas sampled by the purse seine and trawl in early to mid June. The selection of samples for DNA analysis may have contributed to the differences, but the differences may also indicate that ocean-type fish are more common over deeper water at this time of year. There were differences in set locations (Figure 5) and some small differences in the dates of the surveys, but the reasons for the very different population composition at the surface in the early June trawl and purse seine surveys remain to be determined.

The July trawl survey captured a larger percentage of ocean type fish in the surface sets (56%) than in the June trawl sets (15%). The percentage of stream-type fish increased slightly with depth with 51% in the 15-29 m stratum and 59% in the 30-44 m stratum. The percentage of stream-type fish was 94% in the 45-59 m stratum (Figure 6). As previously shown, there were more fish deeper in the water column in July. The fish sampled for DNA that were ocean-type fish were slightly larger in the surface 14 m than in the deeper strata except for the three fish below 44m (Table 2). The lengths of the stream-type fish that were sampled for DNA increased slightly with depth except for the 45-59 m stratum, in which the average length was much larger than at the surface. Because the abundances were larger below the surface 14 m, it appears that in July, the larger stream-type fish were at deeper depths, but not the ocean-type fish.

Juvenile ocean-type chinook salmon in the August purse seine represented 86% of the catch which is similar to the 79% observed in the June purse seine survey (Figure 7). Populations originating from the east side of Vancouver Island continued to be abundant, representing 59% of the catch compared to 40% in the June purse seine survey. The catch composition from the August purse seine survey is not directly comparable to the July trawl catch because of the increasing abundance of the late ocean entry, South Thompson populations. However, there is evidence that the east Vancouver Island populations were distributed throughout the Strait of Georgia, as observed in the June purse seine and July trawl surveys.

There were major changes in the population composition in the September survey compared to the earlier surveys. There was a new dominance of ocean-type fish from the South Thompson population. In September, in the surface sets, the South Thompson fish represented 66% of all populations compared to 3% in the July trawl survey (Figure 8). In the top 30 m in September, the South Thompson populations and other ocean-type juvenile chinook salmon represented about 78% of all populations. There was a large increase in average length below 44 m (Figure 2). However, the abundances below 44 m were small relative to those in the surface 44 m (Figure 1). The average lengths of the ocean-type fish in the fish sampled for DNA were larger in the deeper strata (Table 2). The average lengths of the stream-type fish in this sample increased substantially with each stratum (Table 2). In general, it appears that after the initial few weeks in the ocean, the faster growing or larger stream-type and ocean-type fish move down in the water column.

Population depth distributions in the trawl survey

Life history type was determined for 1,533 fish from the three trawl surveys using DNA. There were 619 fish in the June survey that were identified as stream type. The stream-type fish originated in 36 populations (Table 3). Sample size varied from 54 fish to one fish. Populations in the surface 14 m were also found in other strata and any population in the deeper strata was also in the surface stratum. Thus, there was no evidence that specific populations were only at depths deeper than the surface 14 m.

In the July trawl survey, there were 262 fish from 28 stream-type populations and 25 populations were present in the June trawl survey (Table 3). Two of the three populations not in the June sample were from Puget Sound. Thus, 22 of the 36 stream-type populations found in the June survey were present in the July survey. There was no indication of a depth stratification that was specific for a population.

In September, there were 96 fish examined for life history type using DNA that were stream type. There were 17 populations that were also found in June and July samples, and one population found that was in the June sample but not the July sample. There were two new populations. Thus, of the 20 populations, 18 were present in June and 17 in July. There was no indication of a population-specific depth distribution, although about one third of the samples were not in the surface 14 m.

In general, stream-type fish in all three surveys did not show a population-specific depth distribution. If they were found in the surface 14 m, then they were found deeper. Also, if they were found deeper, most often they were also found at or near the surface. Perhaps the most noteworthy observation was that almost one half of the stream-type populations in the June samples were still in the Strait of Georgia in September. This is another indication that conditions in the Strait of Georgia strongly affect the productivity of a population.

There were fewer populations of ocean-type chinook salmon in our trawl catches. In the June survey, there were six populations and 96% of all fish were caught in the surface 14 m (Table 3). All six populations were also found in the July survey along with sixr new populations (Table 3). There was no indication that populations were specific to a particular depth above 45 m and about one half of the fish were in the surface 14 m (Table 3). The 12 ocean-type populations in September were the same populations sampled in July. Ocean-type fish were found to depths of deeper than 60m with 58% in the surface 14 m and 87% in the top 29 m. Similar to stream-type populations, ocean-type populations that were in the catches in June and July remained in the Strait of Georgia through to at least mid September.

Gulf Islands

The waterways around the Gulf Islands were not part of the standard trawl survey; however, they were surveyed in 2010. In July, most (85%) of the fish in the surface 29 m were ocean type. Stream-type populations became more abundant (53%) below 29 m, although the sample size was small (Figure 9). Chinook salmon from the Cowichan River are one of the important populations in management because they are used as an index of the dynamics of other populations. In July 2010, 22% of the populations were from the Cowichan River. This percentage declined to 15% in September (Figure 10). However, in the trawl survey, only 3 Cowichan River fish were captured in the main Strait of Georgia in July and only 2 in September. Thus, juvenile Cowichan River chinook salmon appear to be virtually resident within the Gulf Islands as has been reported in another study (Beamish et al. 2011). The population composition in the Gulf Islands changes only slightly by September (Figure 9). Ocean-type fish continue to dominate the catches, including sets deeper than 29 m. In general, stream-type juvenile chinook salmon were not abundant in the Gulf Islands in September. The dramatic change seen in the main strait when the South Thompson populations became dominant was not seen in the Gulf Islands in September. Perhaps the largest change between July and September in the Gulf Islands was the increase in abundance of chinook salmon from Puget Sound that accounted for 27% of all populations. The residence of the juvenile Cowichan chinook salmon within the Gulf Islands is an example of the restricted dispersal of some populations with the Strait of Georgia. It also indicates that ocean conditions within the Gulf Islands strongly affect the brood year strength of the Cowichan River population.

Summary

1. The genetic population identification base line provides a useable categorization of life history type but the accuracy of the determinations needs further assessment. When scales are used for the assessment, the accuracy and precision of the scale method also needs to be determined.
2. More stream-type juvenile chinook salmon are found in abundance in deeper water in the summer and fall while more ocean-type fish tended to remain close to the surface. However, there was little evidence of depth stratification of populations

3. The purse seine surveys caught more ocean-type fish than the trawl surveys and many of these fish were from populations originating on the east coast of Vancouver Island. The reason may be that the purse seine fished closer to shore or in areas that were sheltered form winds and strong currents. However, the reasons may also relate to sample selection. It has not been determined if the differences resulted from sampling biases or from distributional differences among populations.
4. The surveys in the Gulf Islands showed that one population, the Cowichan River population, remained in the confinements of the waterways apparently until they migrated out of the Strait of Georgia and offshore late in the year. This is evidence of a major population rearing in the early marine period for a prolonged period in a restricted area near their natal river.
5. There was a major shift in the population composition of juvenile chinook salmon between the July trawl survey and the September trawl survey. There was a large influx of the South Thompson, ocean-type population in the main area of the Strait of Georgia, but not in the Gulf Islands. This major, structural change was a result of smolts from the South Thompson populations entering the Strait of Georgia 6 to 8 weeks later than most other juvenile chinook salmon and a disappearance of most of the juvenile chinook salmon that were in the surface 29 m in July before the arrival of the South Thompson populations. The juveniles of the populations that were present in July must have died of left the strait. An acoustic tagging study in June/July 2008 tagged 148 chinook salmon with an average length of 14.8 cm and a range of 12.0 to 20.5 cm. Only 2 of these fish were detected leaving the Strait of Georgia. (Neville et al. 2010). It is important not to over-interpret this tagging study until more is understood about the use of these acoustic tags and the accuracy of their detection. However, it does appear that there was a substantial mortality of these tagged fish in the Strait of Georgia in 2007, possibly indicating that there is a large mortality of juvenile chinook salmon in the summer months.
6. The early marine period is now generally accepted as the time when survival is strongly affected by the conditions affecting growth. MacFarlane (2010) showed

Conclusion

The behaviour of chinook salmon populations in the Strait of Georgia in the critical marine period needs to be considered in the stewardship of chinook salmon populations. Of immediate importance is the recognition that late ocean entry, ocean-type chinook salmon are surviving better than the majority of fish from populations that enter the ocean earlier (Beamish et al. 2010). These late ocean entry fish are entering a warmer and less saline habitat where they remain for about three months. Thus, these fish appear to be adapted to an early marine environment that might become more typical in the Strait of Georgia in future decades.

It was recognized some time ago that adult chinook salmon had different behaviours that distinguished them as separate populations during their pre-spawning and spawning periods. The smolts from these various populations were recognized as having different life histories or at least different and consistent behaviours. It is relatively new to recognize that after entering the ocean some populations have distinct and persistent behaviours relating to their preferred rearing areas and ocean entry times. This is more than something of interest to the curious because the survival of chinook salmon entering the Strait of Georgia has declined to precipitously low levels without explanation (Beamish et al. 2011). Many years ago Bill Ricker advised that he had learned to expect the unexpected when studying Pacific salmon. The numerous life history types during the various life history stages would be expected to respond unexpectedly to a randomly changing environment. However, the trend in the environment in the Strait of Georgia is not random and is changing in a way that populations of chinook salmon in the Strait of Georgia may need very specific components within the resilience of all populations to survive into the future at abundance levels that allow fishing.

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Table 1. Population composition of juvenile chinook salmon samples from the trawl and purse seine surveys in 2010. Colours identify major population groups with the specific populations listed below for each colour.

Mid-Upper Fraser	Upper Fraser	Lower Fraser	South Thompson (ocean)	Lower Thompson
Baezaeko	Bowron	Birkenhead	Lower Shuswap	Coldwater
Baker	Goat	Chilliwac@Stav	Lower Thompson	Deadman
Chilko	Holmes	Harrison	Little	Louis
Cottonwood	Horsey	Maria Slough	South Thompson	Nicola
Kuzkwa	James	Upper Pitt		Spius
Lower Cariboo	Kenneth	W Chilliwack		Upper Coldwater_SP
Lower Chilcotin	Morkill			Upper Spius_SP
Nazko	Ptarmigan			
Nechako	Salmon@PG	**Vancouver Island (east coast)**	**South Thompson (stream)**	**North Thompson**
Portage	Slim	Nanaimo_F	Bessette	Barriere
Quesnel	Tete Jaune	Nanaimo_SP	Duteau	Blue
Taseko	Torpy	NanaimoUpper	Eagle	Clearwater
Upper Cariboo	Willow	Puntledge_F	Salmon@SA	Finn
Upper Chilcotin		Puntledge_Su		Lemieux
		Quinsam		N Thompson@Main
				Raft

Southern Mainland	Puget Sound	Cowichan River	Vancouver Island (west coast)
Cheakamus_F	Nooksack_SP@Ke	Cowichan	8702Gold
Cheakamus_S	Serpentine		Megin
Homathko	Skagit_Su		San Juan
Porteau Cove	Snohomish		Sooke
	Soos Cr_H		Toquart
	Stillaguamish Su		
Northern Mainland	**Upper Columbia**		**Juan de Fuca**
Kilbella	Wenatchee_Su		Elwha_F
Kitlope			

Table 2. Mean length in mm (standard deviation) and sample size (N) for ocean and stream life history types determined by DNA for each depth stratum for the three trawl surveys.

Survey	Depth	Length	Ocean type (± S.D.)	N	Length	Stream type (± S.D.)	N
June	0-14 m	100 mm	(23.2)	108	130 mm	(21.9)	541
June	15-29 m	125 mm	(4.9)	3	122 mm	(22.5)	34
June	30-44 m	143 mm	(0.0)	1	119 mm	(12.6)	12
June	45-59 m	-	-	-	122 mm	(16.1)	29
July	0-14 m	116 mm	(20.8)	118	149 mm	(28.1)	88
July	15-29 m	116 mm	(19.0)	58	154 mm	(23.8)	64
July	30-44 m	111 mm	(16.8)	43	152 mm	(25.0)	65
July	45-59 m	144 mm	(8.1)	3	162 mm	(15.2)	45
September	0-14 m	155 mm	(26.1)	133	189 mm	(40.3)	27
September	15-29 m	158 mm	(29.1)	67	196 mm	(37.6)	20
September	30-44 m	172 mm	(22.5)	22	212 mm	(37.2)	20
September	45-59 m	255 mm	(0.0)	1	233 mm	(18.2)	13
September	60+ m	199 mm	(46.3)	6	240 mm	(27.3)	15

Table 3. The number of stream-type and ocean-type populations at each depth stratum for the three trawl surveys.

Trawl survey	Sample size	Depth stratum 0-14 m	15-29 m	30-44 m	45-59 m	60+ m
		Number of stream-type populations (number of fish)				
June	619	36 (544)	12 (34)	6 (12)	10 (29)	-
July	262	28 (88)	25 (64)	16 (65)	16 (45)	-
September	96	20 (27)	12 (20)	10 (21)	8 (13)	10 (15)
		Number of ocean-type populations (number of fish)				
June	106	6 (102)	1 (3)	1 (1)	-	-
July	221	12 (117)	8 (58)	10 (43)	3 (3)	-
September	229	12 (133)	7 (67)	6 (22)	2 (3)	3 (4)

A dash indicates that there were no samples.

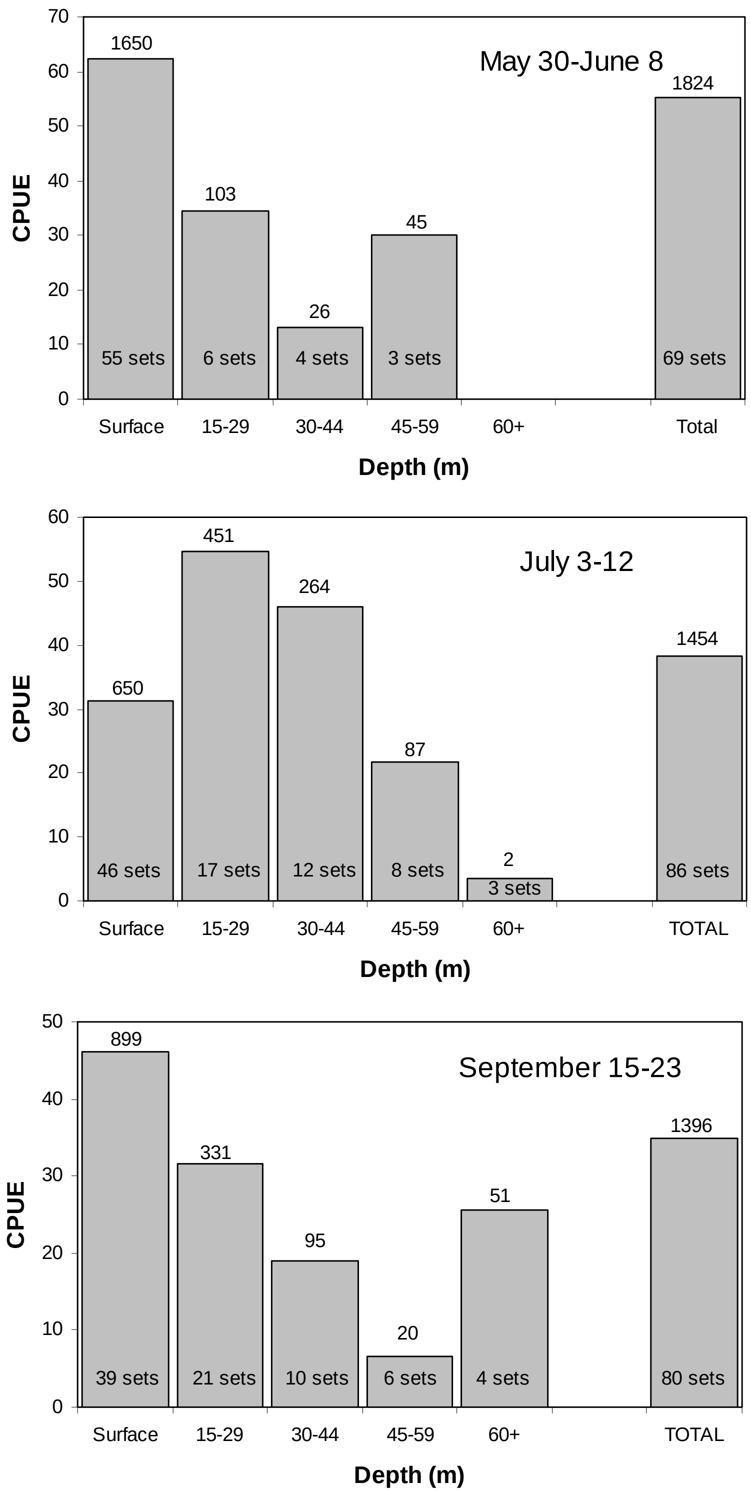

Figure 1. CPUE (catch/hour) of juvenile chinook salmon in the Strait of Georgia during the standard trawl surveys in 2010. The number of sets is identified in each bar and the number of fish is at the top of each bar.

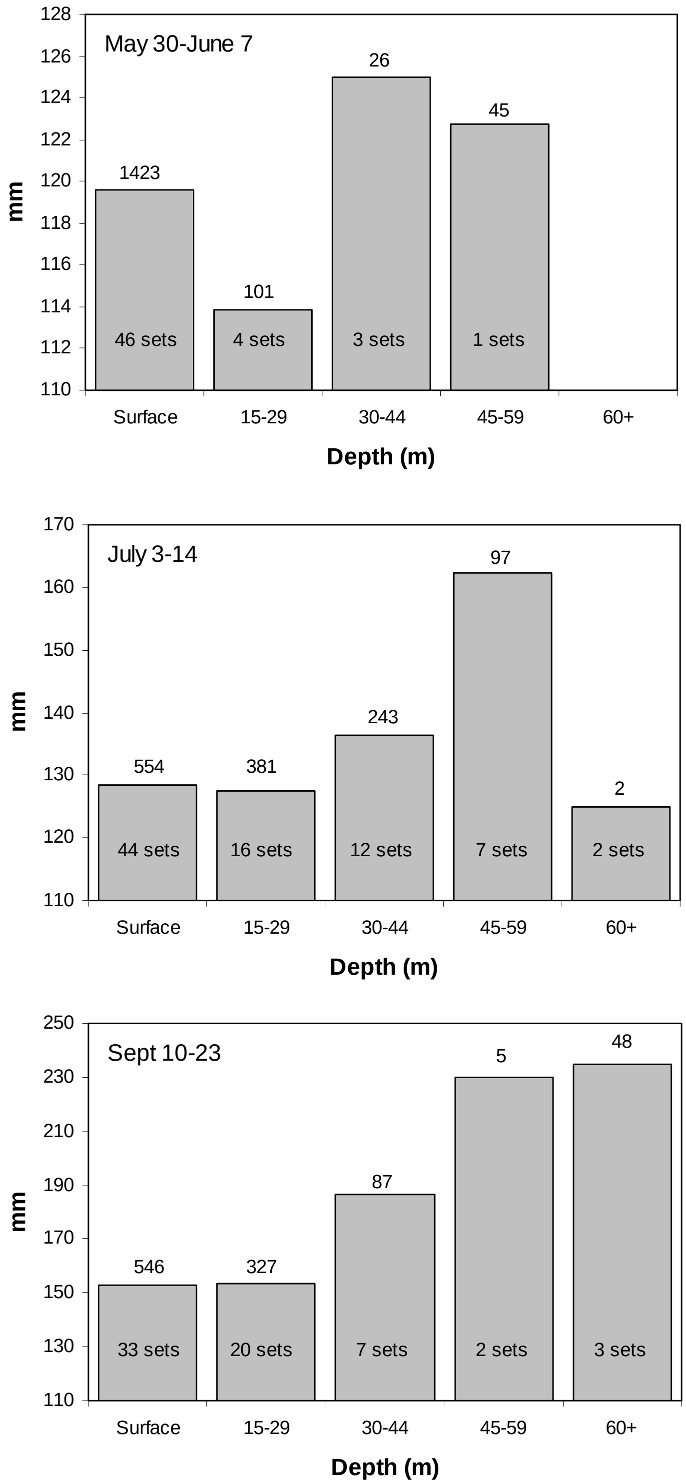

Figure 2. Average length by depth for all juvenile chinook salmon measured in the standard trawl surveys in the Strait of Georgia 2010. The sample size is at the top of each bar.

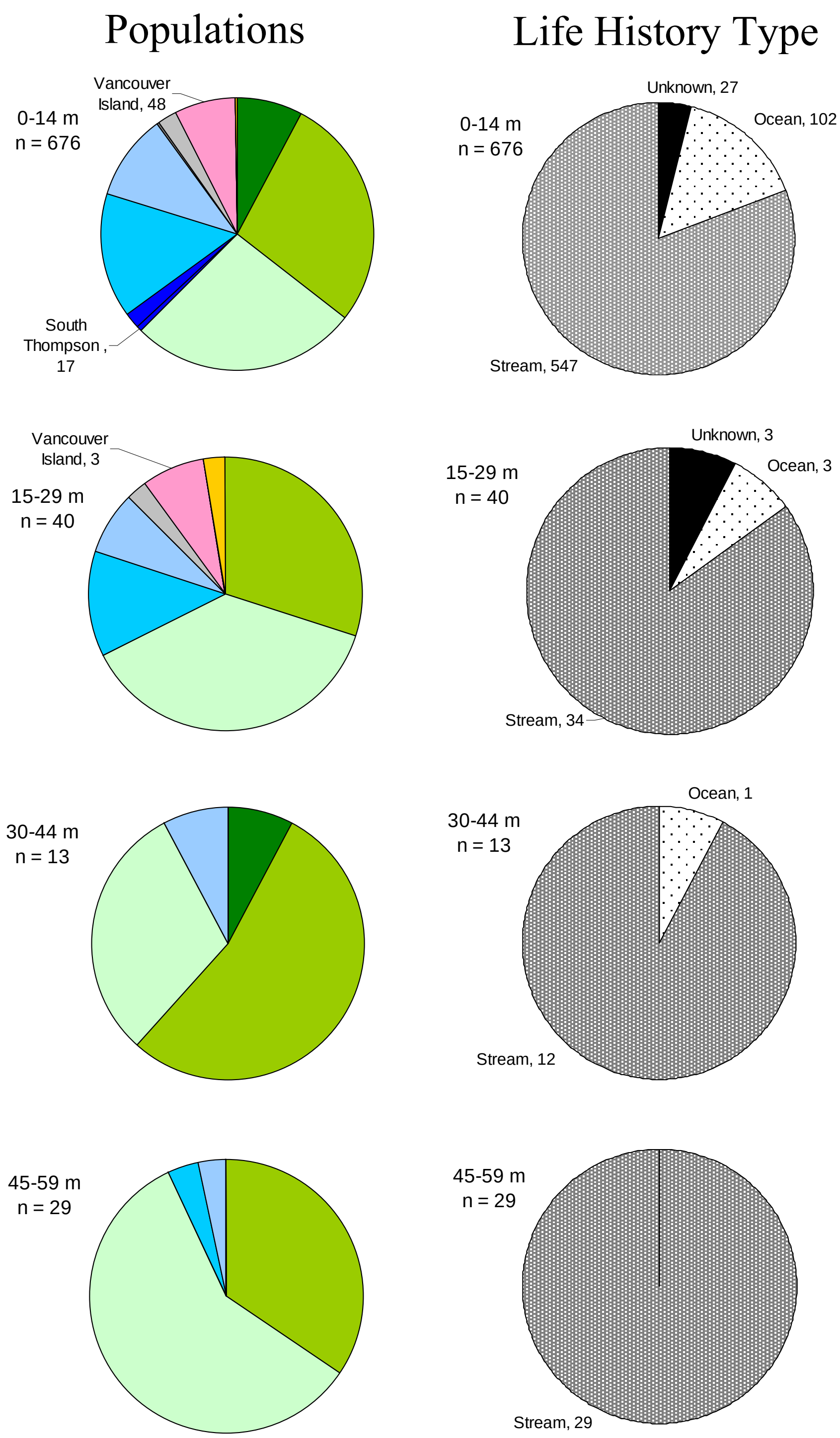

Figure 3. Results of DNA analysis of juvenile chinook salmon captured in the May 30-June 8 trawl survey. See Table 1 for key to colours of populations. South Thompson, Vancouver Island (east coast), Cowichan River and Puget Sound populations are identified if present. The relative numbers of ocean- and stream-type fish are shown as gray and white, unknown life history type is black.

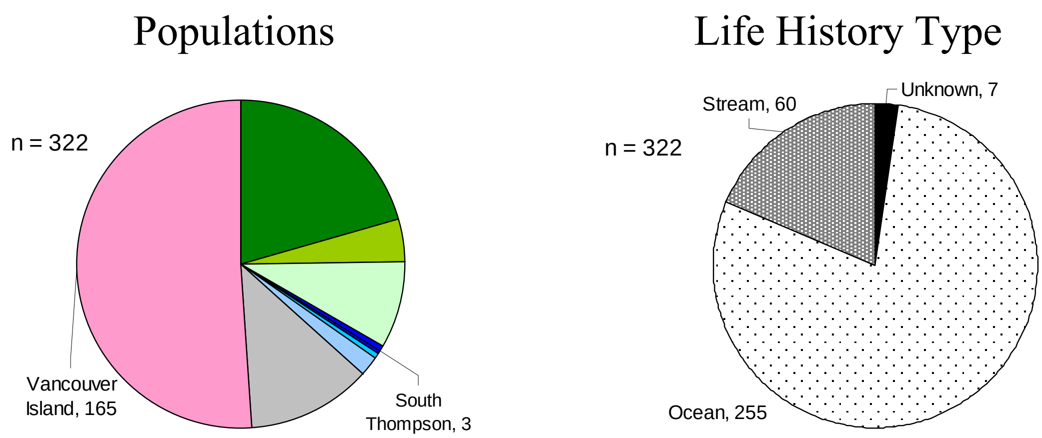

Figure 4. Results of DNA analysis of juvenile chinook salmon captured in the June 10-21, 2010 purse seine survey. See Table 1 for key to colours of populations. South Thompson, Vancouver Island (east coast), Cowichan River and Puget Sound populations are identified if present. The relative numbers of ocean- and stream-type fish are shown as gray and white, unknown life history type is black.

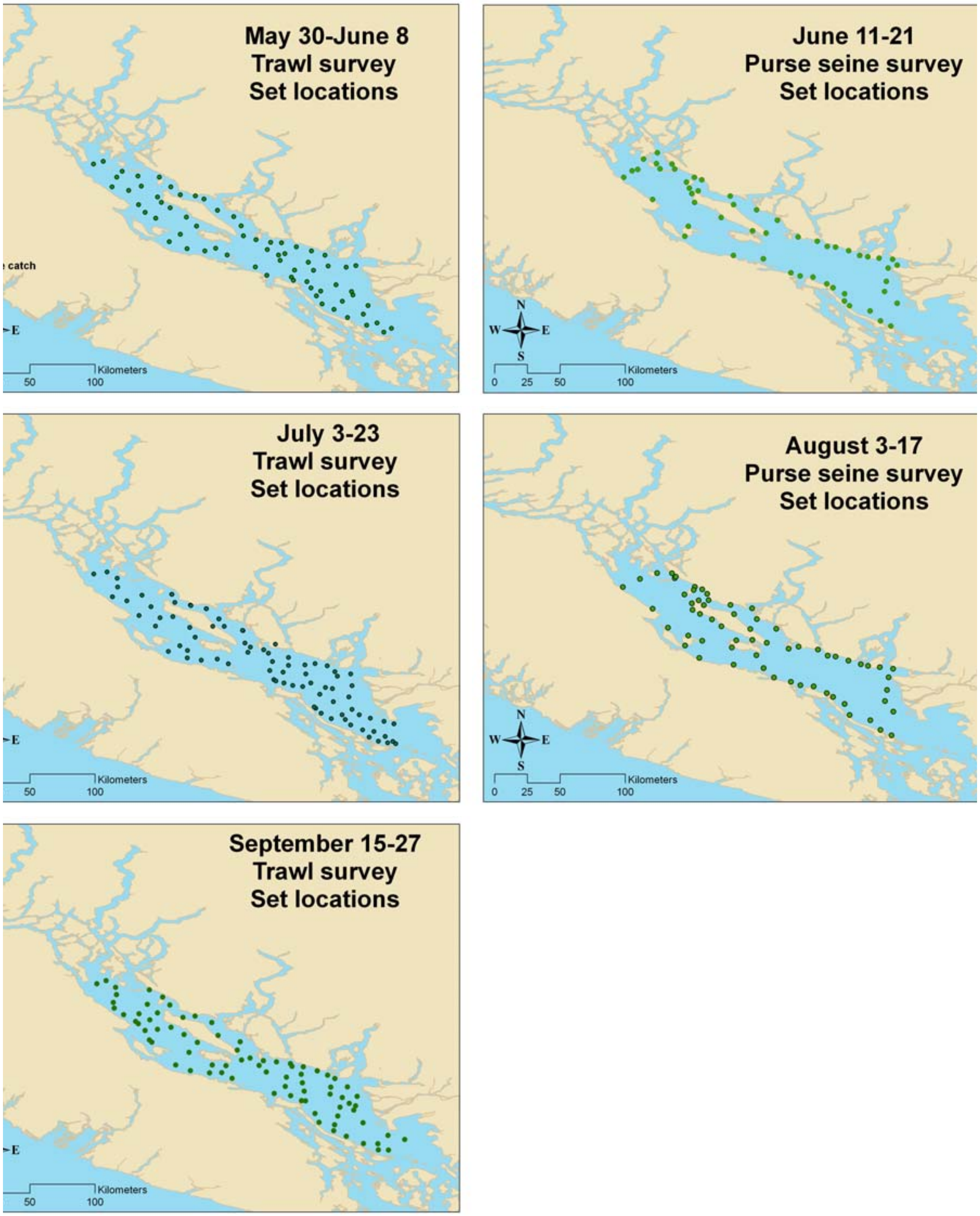

Figure 5. Set locations for the trawl and purse seine surveys in the Strait of Georgia in 2010.

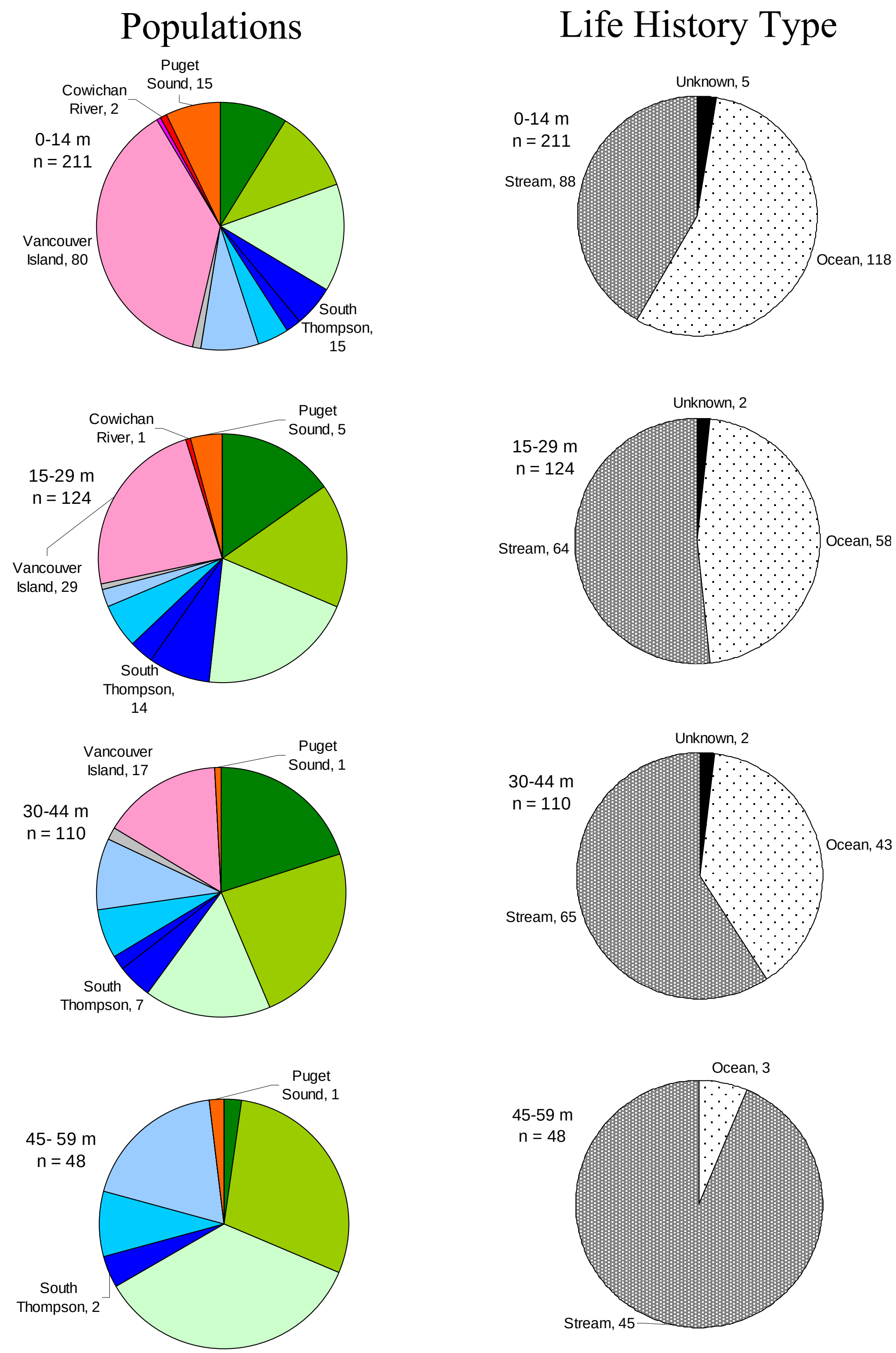

Figure 6. Results of DNA analysis of juvenile chinook salmon captured in the July 4-23 trawl survey. See Table 1 for key to colours of populations. South Thompson, Vancouver Island (east coast), Cowichan River and Puget Sound populations are identified if present. The relative numbers of ocean- and stream-type fish are shown as gray and white, unknown life history type is black.

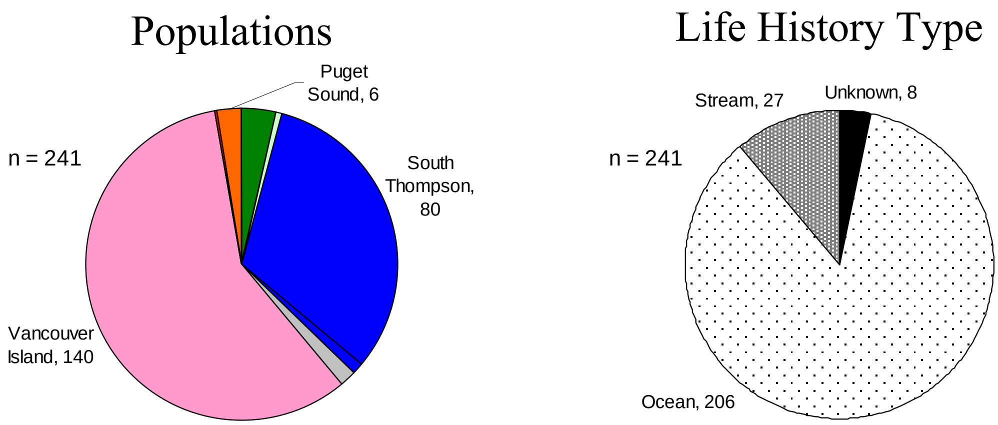

Figure 7. Results of DNA analysis of juvenile chinook salmon captured in the August 13-17 purse seine survey. See Table 1 for key to colours of populations. South Thompson, Vancouver Island (east coast), Cowichan River and Puget Sound populations are identified if present. The relative numbers of ocean- and stream-type fish are shown as gray and white, unknown life history type is black.

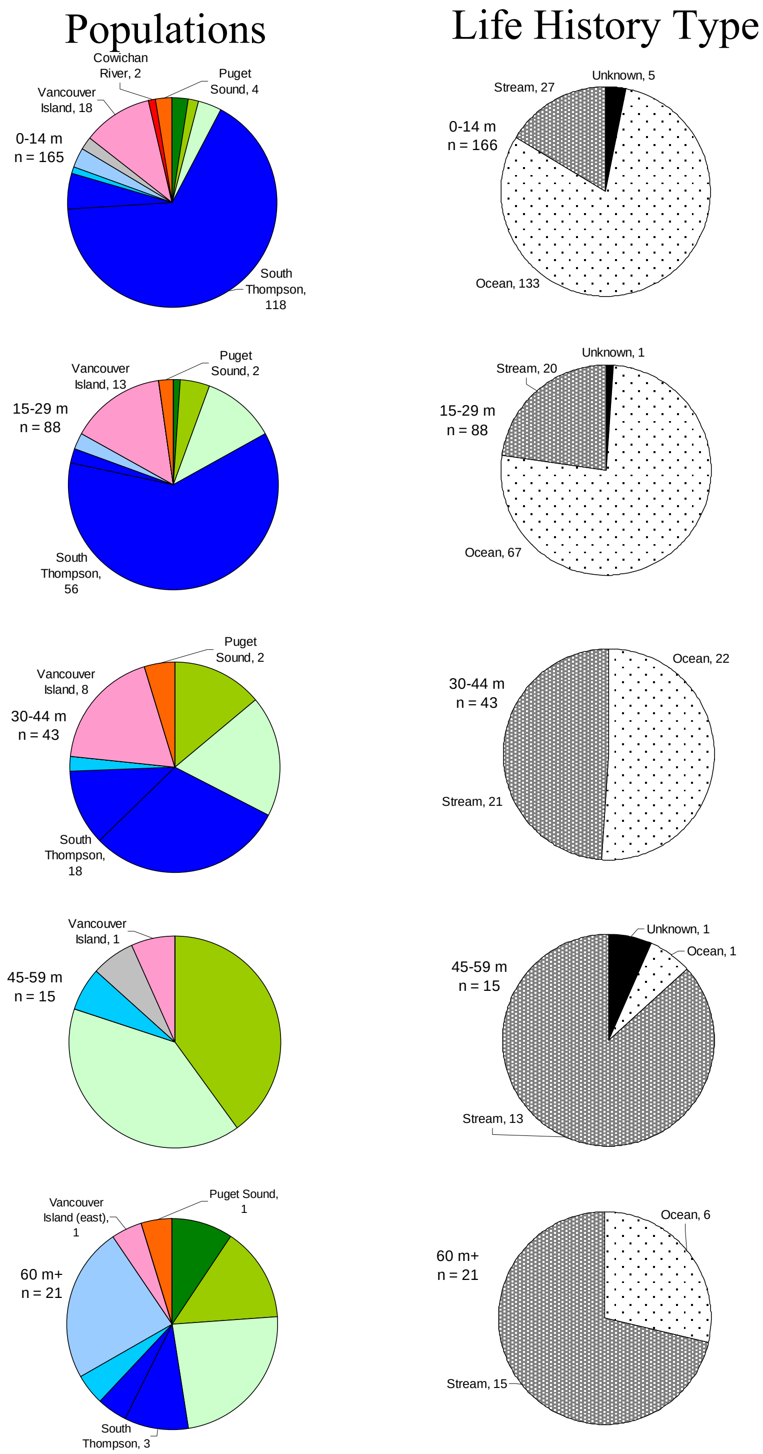

Figure 8. Results of DNA analysis of juvenile chinook salmon captured in the September 15-27 trawl survey. See Table 1 for key to colours of populations. South Thompson, Vancouver Island (east coast), Cowichan River and Puget Sound populations are identified if present. The relative numbers of ocean- and stream-type fish are shown as gray and white, unknown life history type is black.

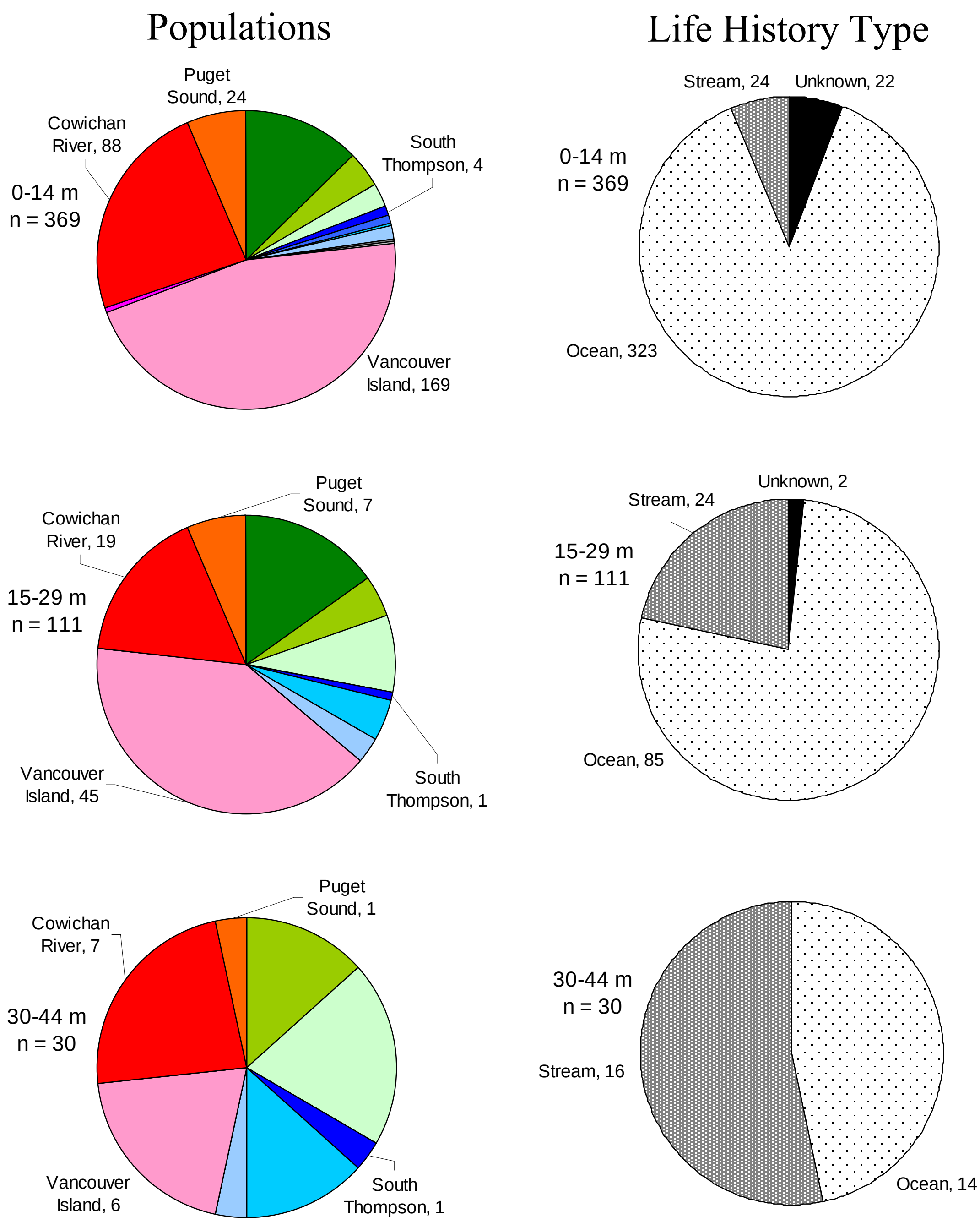

Figure 9. Results of DNA analysis of juvenile chinook salmon captured in the July 21-23 trawl survey of the Gulf Islands. See Table 1 for key to colours of population. South Thompson, Vancouver Island (east coast), Cowichan River and Puget Sound populations are identified if present. The relative numbers of ocean- and stream-type fish are shown as gray and white, unknown life history type is black.

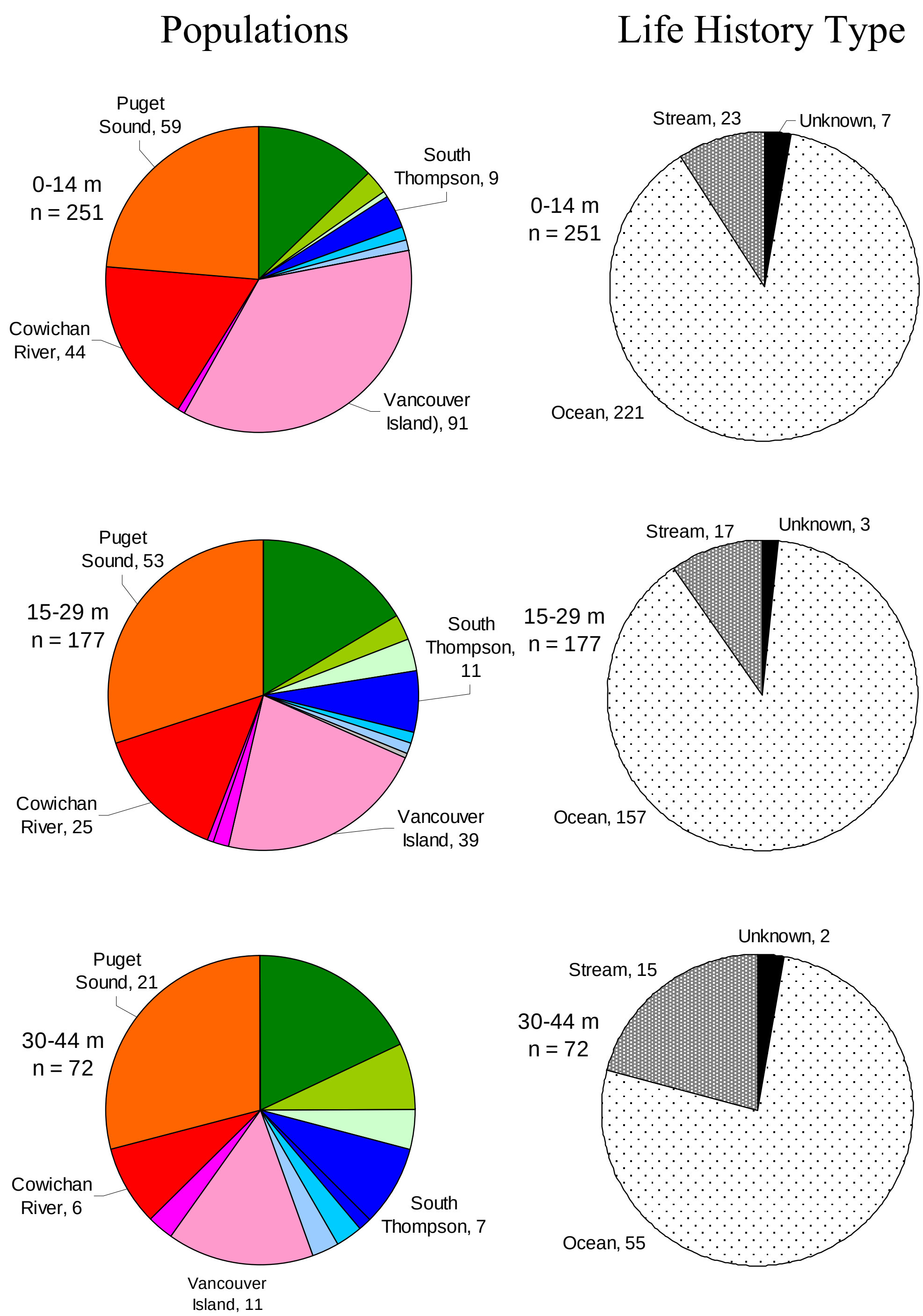

Figure 10. Results of DNA analysis of juvenile chinook salmon captured in the September 10-12 trawl survey of the Gulf Islands. See Table 1 for key to colours of populations. South Thompson, Vancouver Island (east coast), Cowichan River and Puget Sound populations are identified if present. The relative numbers of ocean- and stream-type fish are shown as gray and white, unknown life history type is black.