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Report on the 2004 Pacific Ocean Shelf Tracking (POST) Project- Objectives, Goals, & Initial Results

by

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Abstract

Little is known of the early marine life history of Pacific salmon in the continental shelf environment, because of the limitations of traditional sampling methods and an inability to understand how animals move (and die) in this environment. An improved scientific knowledge of this period is critical to understanding differences in marine survival affecting many North American stocks of Pacific salmon. Here we describe the results from the 2004 demonstration project in which a large-scale marine telemetry array was built to address these problems. An array consisting of 135 individual acoustic nodes was constructed, and the movements of 1,051 British Columbia salmon smolts over the array was evaluated. The overall size of the array was 1,500 kms. The main array consisted of 6 linearly spaced acoustic "curtains" of >20 kms length, with nodes spaced to provide an essentially complete census of tagged animals moving across it . Additional nodes were placed at river mouths to provide separate measurements of freshwater survival post-release and subsequent survival in the ocean. A sub-array was placed in Howe Sound, a 40 km fjord, to measure the earliest phase of marine survival.

We obtained precise estimates of stock-specific run timing, speed and direction of movement, plus survival. The results allow a direct comparison of survival differences between stocks and species of salmon, as well as a comparison of hatchery versus wild survival. Overall detection rates for individual tagged smolts over the ocean array was 91% and can be improved in future. We also obtained detailed information on the distribution and movements of 24% of all the acoustically tagged green sturgeon released in 2003 by an unrelated research project in the United States.

The scientific validity of the array concept has been proven, and a permanent array offers the exciting prospect of being able to conduct precise long-term measurements in the sea for animals as small as 12 cms.

Introduction

In this report we describe the 2004 results from a large-scale project to demonstrate the biological utility of permanent large-scale marine telemetry arrays. Initially planned as a continental-scale acoustic telemetry array for the west coast of North America, the array concept has potential application in any area of the world's oceans where continental shelves exist. The array is one of seven major field projects being sponsored under the Census of Marine Life.

The Census of Marine Life (CoML) is a decade-long program to promote and fund research assessing and explaining the diversity, distribution, and abundance of species throughout the world's oceans. Related activities integral to this research include the design and implementation of standard databases for marine species in collaboration with other international efforts launched recently, and the design and implementation of innovative biological sampling techniques for the marine environment. Outreach and education efforts help inform the public about the CoML's potential and actual

contributions to knowledge, and help tune the program to the concerns and priorities of governments, commercial and recreational fishers, environmental groups, the research community, and other stakeholders in the oceans.

POST, the Pacific Ocean Shelf Tracking project, is one of 7 major field programs within the Census of Marine Life (CoML). The Census is focussed on developing a new era of marine research around the world, with a strong international commitment and regional committees which have the ambitious goal of initiating $1 billion of new research by 2010. CoML's web page (www.coml.org) provides further information on the structure and function of the Census.

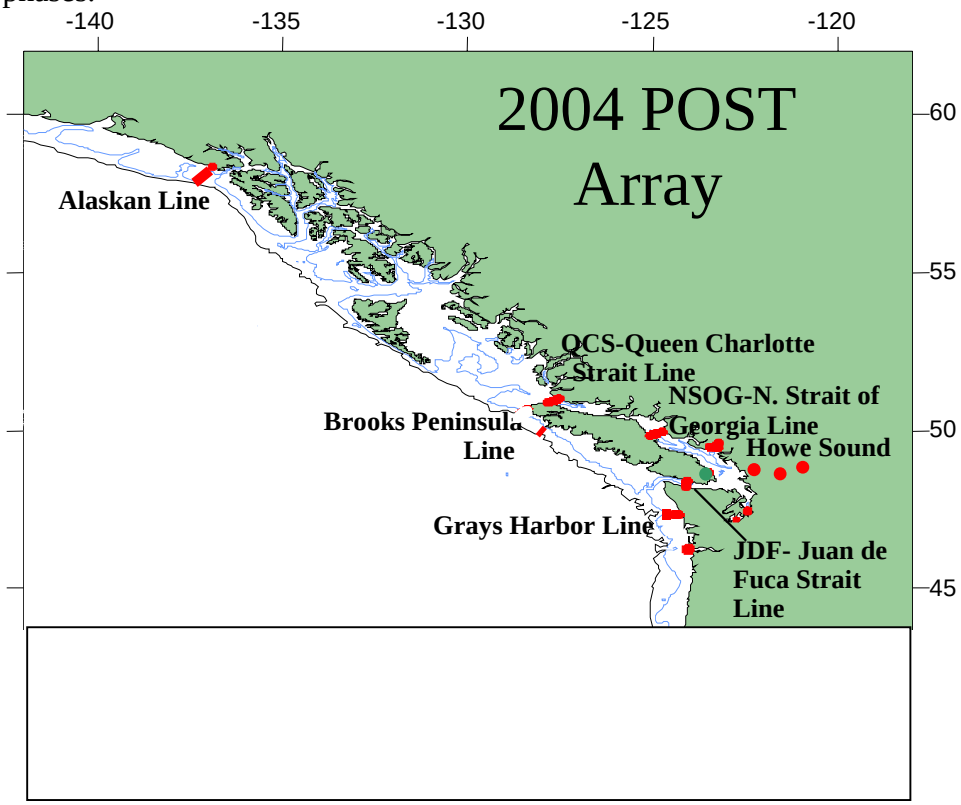
POST and its sister project TOPP (Tagging of Pacific Pelagics) are two of CoML's field projects, and both are focussed in the Pacific Ocean. TOPP is primarily aimed at the use of the various archival tag technologies on large pelagic animals in the offshore region. In its first pilot phase (2000-2002), POST also examined the use of archival tags in Pacific salmon but in its follow-on demonstration phase (2004-05) POST has chosen to focus solely on a single technology: the development of a permanent acoustic tracking array for (initially) the continental shelf of the west coast of North America. This refinement in POST's focus reflects both a strategic choice to deal with the continental shelf region-- where the world's major fisheries resources are largely located—and because much of the decline in marine survival of Pacific salmon likely occurs in this region.

In this report we focus on describing the results from the 2004 field season, which was intended to demonstrate the possibility of achieving an essentially complete census of the migration pathways and fate of individual salmon smolts as they migrate out of the Strait of Georgia and along the continental shelf as far north as Icy Strait (SE Alaska). As the field work to complete the final recovery of the array in 2004 is still underway at the time of writing, we focus primarily on an overview of how the POST array was configured in 2004 and the initial results. The key conclusion is that an essentially complete census of individual free-swimming salmon smolts is now scientifically feasible, providing detailed information on survival, speed of movement, and direction of migration.

Description of the array

In 2004, a prototype acoustic array was deployed in the continental shelf area of Western North America from Cape Elizabeth (just north of Grays Harbor, Washington; 47° 23.8’N, 124° 20’W) to Cape Spencer, Alaska, just north of the SE Alaska panhandle (58° 24.5’N, 137° 8.8’W; Figure 1). Three open shelf lines in Washington and Alaska and from Vancouver Island extended perpendicular from near shore to approximately half-way across the shelf (100m depth contour). Acoustic lines in the Strait of Juan de Fuca, Queen Charlotte Strait, and northern Strait of Georgia were each over 20 kms long, and were deployed to provide a complete census of all tagged animals entering or exiting the Strait of Georgia.

Additional acoustic lines were placed within Howe Sound, a 40 km long fjord system within the Strait of Georgia, and individual receivers were also placed near the mouths of multiple river systems to measure survival of smolts from freshwater release to the river mouth. This allowed compartmentalising the measured survival post-release into freshwater and marine phases.



The array was deployed on the seabed starting in mid-April and final recovery began in September. The entire array (excluding the Alaska line) was also recovered once in July, the data downloaded, and then physically re-deployed. The Alaskan line is scheduled for recovery in early October. As the data demonstrated rapid movement of tagged salmon smolts out of the Howe Sound array and few residual fish within the Howe Sound system at the time of initial recovery (16 July), equipment used in Howe Sound was not re-deployed there, but held in reserve to replace equipment losses elsewhere (which were relatively low).

A total of 1,051 salmon smolts from 5 species were surgically implanted with acoustic tags in British Columbia. With the exception of the tags surgically implanted into Sakinaw Lake sockeye, these tags were the smallest available and were programmed in such a way to have a relatively long-life (4.5 months) and to transmit continuously until the tag's battery was exhausted.

Because of the importance of determining the run-timing of the threatened adult Sakinaw Lake sockeye back to Canada, a slightly larger tag was surgically implanted into Sakinaw sockeye smolts. These tags were programmed so that the tags transmitted continuously until early September 2004, at which time the tags shut down and only power the internal clock. These tags are programmed to re-activate and begin broadcasting in mid-June 2006, when the surviving adults will return to Canada. As the migratory timing of adult Sakinaw sockeye is critical to the management of the British Columbia sockeye fishery

and is only known for a single Sakinaw sockeye (that was spaghetti tagged in July 1924), these tags may provide valuable information on the overlap in run timing of this threatened stock with abundant co-migrating salmon stocks.

A co-ordinated study using ca. 900 spring chinook from the Snake River (Columbia River system) were also implanted by Professor Carl Schreck (Oregon State University, Corvallis, OR USA 97331-3803; Carl.Schreck@orst.edu) with compatible coded acoustic tags, and approximately 150 coho from south Puget Sound were similarly implanted (Scott Steltzner, Squaxin Island Natural Resources, 2952 S.E. Old Olympia Hwy, Shelton, WA 98584; ssteltzner@squaxin.nsn.us). In this report we focus on the results from the Strait of Georgia study.

All animals were surgically implanted under full anaesthesia using a combination of Metomidate-HCl (1 ppm) as a pre-operative sedative and MS-222 (40 ppm) buffered with sodium bicarbonate (80 ppm) for anaesthesia. All animal care plans were reviewed by the relevant Canadian Council on Animal Care site committees, and permits for capture and tagging of wild smolts were provided by the appropriate federal or provincial agencies. Following surgery, smolts caught in the wild were held for observation and generally released at dusk of the following day, allowing for a minimum of 24 hrs to assess response to tagging. Hatchery smolts were held for up to several weeks prior to release. The overall mortality rate (all groups combined) was 3.7%. The majority of this mortality occurred in the first stocks tagged, suggesting that the effect was probably associated with start-up problems for the field crews (likely anaesthesia problems). In late season tagging there was usually no mortality associated with tagging of a standard release group of 100 smolts from a stock.

Results

Table 1 provides a summary of the numbers tagged by stock and species, whether the group was composed of wild smolts (caught in rotary screw traps placed in the rivers), hatchery origin, or unknown provenance (in one case, unmarked hatchery chinook smolts were released into the river prior to the wild smolts being captured and tagged).

In almost all cases, good measures of freshwater survival post-release were obtained, as well as detailed information on the numbers of tagged smolts of each stock that exited from the Strait of Georgia using the Strait of Juan de Fuca (where a 22 km listening line was deployed) versus exiting via the northern exit, passing first over the northern Strait of Georgia line (21 kms long) and then out through Johnstone Strait and then across the 20 km Queen Charlotte Strait acoustic listening line.

Overall detection efficiencies were 91%. We defined this measure as 100% minus the percentage of tagged animals detected on one or more acoustic listening lines distant from the release site but which were not first detected on an inner line. In other words, nine percent of tagged animals had moved across an earlier line without being detected. This detection efficiency probably can be increased slightly in future years. Some of the

acoustic elements were pulled out of position (probably by trawlers) during the 2004 study. In addition, reducing the spacing between acoustic elements also would increase the detection rate.. However, given the already high detection efficiency a more productive future design would involve the construction of more lines, giving more opportunities for independent repeated detections and a finer scale understanding of movement patterns and survival of each stock.

Marine survivals and rates and patterns of movement showed major differences between species and significant evidence for some surprising differences in survivals between some stocks of the same species. These detailed results will be reported later. The speed and timing of exit from the Strait of Georgia was precisely defined for all species other than coho, which appear to have either remained resident inside the array or to have died. A few late season detections in August and September suggested that the former was the more likely explanation.

Table 1. Summary of tagging rates and subsequent detections in the ocean. A detailed breakdown by acoustic line is also available, as well as data on position and abundance along each line. Detailed results will be discussed elsewhere.

Species	Stock	H/W	# tagged	Total tags subsequently detected*
Steelhead	COLDWATER R (Thompson)	W	31	16
	CHEAKAMUS R (Squamish)	W	51	35
	ENGLISHMAN	W	67	53
	KEOGH R	H	92	65
	KEOGH R	W	78	60
Coho	CHEAKAMUS R (Squamish)	H	100	36
	COLDWATER R (Thompson)	H	40	1
	QUALICUM	H	97	3
	NIMPKISH	H	99	78
	SOUTH PUGET SOUND			1
	KEOGH R	W	107	105
Chinook	COLDWATER R (Thompson)	H	49	2
	COLDWATER R (Thompson)	W	2	1
Sockeye	CULTUS LAKE	H	100	61
	SAKINAW LAKE	H	97	41
Dolly Varden	KEOGH Adults	W	8	6
	KEOGH Juveniles	W	30	17

* Excludes false positives occurring at the Keogh river mouth because of unusual conditions not duplicated elsewhere

One final biological result will be summarised here. Some excess channel capacity on the acoustic receivers forming the array elements was programmed to detect one of the more commonly used acoustic tag codes used by researchers unaffiliated with the POST project. Although the North Pacific Anadromous Fish Commission normally receives reports only on Pacific salmonids, we are pleased to report that we also collected detailed information on the movements of the anadromous green sturgeon (*Acipenser medirostris*). Only three known spawning populations occur in North America (the Rogue River in southern Oregon and the Klamath and Sacramento Rivers in California) and all are considered threatened. Of 174 green sturgeon tagged by US investigators in prior years, we have now detected 42 of these animals, or 24% of the tagged population. These animals have primarily been detected on the outer shelf lines near Grays Harbor and Brooks Peninsula and only a few animals have been detected in the Strait of Juan de Fuca. Seven of these animals have been detected on multiple listening lines, all of which showed southward movement, despite all animals having originally been tagged well to the south of the POST array. The episodic nature of these detections, with individual animals being detected on a given line for substantial periods of time (days to several weeks) then no subsequent detections being recorded, suggests that the green sturgeon take up residence for a period of time then move elsewhere. In some cases, these movements can be quite rapid, with three individuals travelling the 480 km distance between Brooks Peninsula and Cape Elisabeth in 4, 6, and 7 days.

Discussion

Fisheries research on anadromous fish such as salmon and sturgeon has been greatly hampered by the lack of any real ability to follow the survival and movements of the animals at sea. This observation is particularly true for the juvenile phase, since conventionally tagged juveniles are rarely caught in the fisheries. The first year of the POST project has been very successful, with a demonstrated efficiency of at least 91% for detection of even small salmon smolts (12-15 cms FL), and precise measurements being obtained of movement rates, survival, and migration routes on both an individual and a stock-specific basis.

The majority of the acoustic listening lines that we deployed for 4~5 months (from April to September) exceeded 20 kms in length, which is equivalent to the width of the continental shelf off the west coast of North America. As a result, we are confident that the acoustic tracking array can be deployed permanently to form a year-round telemetry system that can simultaneously track many species of marine fish and mammals with very high efficiency. We have already demonstrated from this year's work that these technical results can be obtained with high efficiency for anadromous fish such as salmon and sturgeon. As the tags appropriate for use on very small salmon smolts (>12 cms) have lifespans of 4.5 months, tracking projects on salmon smolts are now possible that will extend from the time of leaving freshwater (May) until mid-September.

For animals >16 cms FL, we have previously demonstrated that we can successfully implant tags with battery lifespans of 20 months or more. By August, salmon smolts have reached the 20-25 cm range, so a marine tagging program could be conducted as

well which would involve capturing juvenile salmon at sea, surgically implanting a slightly larger tag which could last for the rest of the lifespan of the salmon, and which would allow following the movements of shelf-resident stocks of salmon over multiple years. For those salmon stocks that migrate off-shelf, tags would provide information on what region of the shelf that they leave from, and what region of the shelf that they return to as maturing adults—plus their detailed shelf migration track back to their rivers of origin. Using a combination of DNA analysis of the animals collected at the time of ocean tagging and a series of river mouth arrays to determine survival and river entry timing, a wealth of stock-specific scientific data that is not currently possible can be collected. We believe that once proven the potential for this technology is equally applicable to shelf sea regions of the Asian coast as well.

Conclusions

In conclusion, the 2004 demonstration phase of the shelf tracking array has been very successful. We have shown that biological data of unparalleled precision can be obtained. This data provides important information on the life history phases thought to be of critical importance to salmon management. In the 2005 period the array will be deployed again incorporating new technological refinements that will improve data recovery, reduce costs, and make a multi-year deployment feasible. In 2005 the use of the array will be available at no cost (apart from tag purchase and implantation costs) to interested investigators. Although plans for subsequent years are not finalised, it is intended to have instrumented the entire west coast shelf with 30 permanent acoustic "curtains" by 2010. At this point the array will extend from California to the Aleutians. There is no technical impediment to its extension to the Asian shelf as well.

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