Fish Tagging Forum
Draft Compilation of Tagging Information
2012_10_30 v3

The enclosed compilation of tagging technology information is intended to provide a summary of comparative information derived from tag-specific presentations that have been completed to-date. This compilation will serve three purposes:

1. Provide a basis for determining if there are inconsistencies and/or gaps in the information gathered to-date that warrants further communication with subject matter experts;
2. Provide a basis for defining the focus and level of detail necessary to fulfill the forum objectives related to documenting the current state of knowledge;
3. Provide a base level of common understanding in support of program effectiveness and cost effectiveness evaluations yet to be completed by the Forum.

WHAT IS NEEDED NOW IS YOUR REVIEW AND COMMENT TO MAKE SURE THE COMPILATION MEETS ITS PURPOSE.

We can discuss the results of your review at the next Fish Tagging Forum meeting on December 3rd. However, if you have any input prior to then please send it along.

Here are a few notes to keep in mind related to your review:

1. The rows are aligned with information needs expressed in the FTF charter. This should facilitate our assessment of responsiveness to objectives. Since the previous version of this table, we (Sapere) have grouped like topics together and consolidated rows containing redundant or very similar information.
2. The contents of the cells are almost exclusively based on information from the presentations and meeting notes. Italicized test represents clarifying information based on simple research. Our intention was for this iteration of the summary table to reflect FTF materials and discussions. Final deliverables to the Council may very well include additional information from other resources (e.g., 2009 tagging report, follow-up conversations with subject matter experts, further FTF discussions, etc.). Please provide any comments you have regarding information that is missing, and/or incorrectly represented.
3. Ultimately we want the information in the cells to be consistent and comparable across the technologies. Instances where it is not, indicates an information gap. Please provide comments/input in areas where you perceive a gap to exist. For example, in the second row (Number of fish marked/tagged) ideally we would want to focus our numbers on a) number marked/tagged in the Columbia River Basin; and b) of those in the CRB, what number or proportion are marked/tagged under BPA funded projects. Similarly, in the 3rd row, we'd want to be able to consistently report an absolute number of recoveries/detections or perhaps a recovery/detection rate if absolute numbers are not easily attainable. If there is information/knowledge that you have to fill the gap, and it is based on information that has not been part of the forum to-date, please indicate it as such.

	FTF Charter Objectives	Acoustic	Adipose Fin Clip	Coded Wire tags	Genetic Markers (PBT/GSI)	Otolith Thermal marks	PIT Tags	Radio tags
3a	What fish are tagged	Acoustic tags are utilized primarily for juvenile Chinook, sockeye, lamprey, and steelhead. Acoustic tags are also used to study adult white sturgeon, walleye, bass, and pikeminnow.	Adipose fin clip is used to mark hatchery-origin fish, including Chinook, coho, and steelhead.	Emphasis of the program is on tagging Chinook and coho, with smaller numbers of steelhead and only a few sockeye tagged each year.	Genetic markers can be applied to any species of fish to allow for individual or stock identification. Standardized microsatellite baselines have been previously constructed for coastwide projects for steelhead, sockeye salmon, Chinook salmon and coho salmon.	Chinook, chum, coho, cutthroat, kokanee, pink, steelhead and sockeye species have been thermally marked.	PIT tag technologies have been applied for juvenile or adult salmon, steelhead, sturgeon, bull trout, and lamprey.	Radio telemetry is used to tag juvenile and adult salmonids and lamprey. Juvenile salmonids include yearling and subyearling Chinook salmon, juvenile steelhead, and sockeye.
3a	Number fish marked/tagged	There are currently 65,000 unique JSATS tag codes in the Columbia and Snake river basins. At Chelan County PUD, between 4000 - 4500 juvenile fish are tagged/year per species. At Cougar Dam in 2011, USGS tagged 1000 juvenile Chinook, and at the Detroit project in 2012, the USGS will use 1200 tagged fish.	A 1995 Washington State law and 2003 US Department of Interior law required visual marking of hatchery fish.	About 56 million smolts are coded wire tagged each year at about 260 hatcheries along the West Coast. In CRB, between 22-24 million fish are coded wire tagged.	Under the current BPA-funded project ~90-95% of Snake River spring/summer Chinook salmon and steelhead hatchery broodstock are successfully genotyped and all of their offspring are genetically tagged. Approximately 9 million steelhead and 12 million spring/summer Chinook salmon are tagged each year under the current Snake River PBT project.	12 to 15 million juvenile fish in the CRB are thermally marked and released.	Approximately 2 million PIT tags are used annually in the CRB.	Sample sizes for radio telemetry are driven by a balance of precision needed for question(s), costs, and potential negative impacts on resource. Typically between 3,000 and 7,000 adult salmon or lamprey have been tagged annually.
3a	Number fish or tags recovered/detected	95% detection rate through the mainstem Columbia,	N/A	There is a goal to sample about 20% from each of the fisheries for CWTs; escapement sampling goal of 5% from each spawning ground; 100% sampling of hatchery returns. Total Columbia River catch in 2010 was 616,777, with 75,774 CWTs recovered (12%).	Thousands of fish are being recovered as part of GSI projects in the Pacific Ocean and in the Columbia River basin. At least 5,000 PBT tagged steelhead and 9,000 spring/summer Chinook salmon are sampled per year.	WDFW analyzes 20,000 - 50,000 specimens per year.	About 1 million individual fish with PIT tags are detected per year.	Tags are detected on nearly all mainstem dams on the Columbia and Snake rivers. Over 147 receiver sites in operation each year throughout the CRB.
3a	Entity releasing fish	*USCOE; Grant County PUD ; Chelan County PUD, some USGS and USFWS*	Virtually all coho and spring/summer Chinook raised with the intent of supporting fisheries are adipose fin clipped.	47 federal, state and tribal fish agencies and other private entities tag fish.	IDFG, ODFW, WDFW, USFWS, NPT, IPC	WDFW, OR, NV, ID, Grant County PUD	*ODFW, USFWS, WDFW, NPT, CTUIR, Yakama Tribe (47 federal, state and tribal fisheries agencies and other private entities tag fish)*	USGS, NOAA Fisheries, Chelan PUD, OSU, USACE
3a	Entity recovering/detecting fish	*USCOE; Grant County PUD ; Chelan County PUD, some USGS and USFWS*	State and tribal fishery management organizations.	*ADFW, DFO, ODFW, CDFG, WDFW, Northwest Indian Fisheries Commission, IDFG, Nez Perce Tribe, Quinault Nation, Quileute Tribe, Umatilla Tribes (35 different federal, state and tribal fisheries agencies and other private entities)*	IDFG, ODFW, WDFW, USFWS, NPT, IPC	WDFW, Grant County PUD	*WDFW, UI, USGS, ODFW, USFW, DFO*	USGS, NOAA Fisheries, Chelan PUD, OSU. Proofed data sent to COE.
3a	Purpose of tagging	Acoustic tags address dam passage survival and dam passage behavior in 2-D and 3-D, estimate survival through the estuary, survival of transported fish, and migration and fate of adult fish (as well as lamprey). Acoustic tag studies are able to support identification and evaluation of fish passage technologies, operations, and techniques. The technology can allow managers to better understand fish passage efficiency, spill passage efficiency, route-specific survival, and dam passage survival.	The purpose of fin clipping is to identify particular stocks of fish, such as hatchery-origin fish, as recommended by ISRP. Fin clipping is also used for brood stock management to identify the hatchery-origin fish component in the hatchery and on the spawning grounds.	Provide data on stock-specific migrations, ocean distribution patterns, and migration corridors of juvenile salmonids. Currently, CWT data are used in hatchery management to evaluate rearing and release experiments, estimate adult production, estimate SAR, and manage broodstock.	Used to estimate stock-specific data of wild and hatchery origin fish on ocean abundance, harvest, distribution, survival, and migration timing; estimate direct and indirect harvest of ESA listed salmonids, hatchery adult straying, reconstruct runs, predict adult run abundance, assess stock-specific temporal and spatial distribution of juvenile salmon and steelhead in the Columbia River estuary; estimate stock-specific harvest rates by commercial, recreational, and tribal fisheries in the Columbia River.	Thermal marking enables in-season tracking of adult hatchery salmon through commercial fisheries and onto the spawning grounds. Thermal marking has also provided new research opportunities for life history and population dynamics studies of individual hatchery stocks in high seas and coastal waters. Provides data on age and growth, hatchery versus natural origin, movement patterns, habitat use, and survival.	Data and analyses supported by PIT-tagging include return timing, smolt to adult return (SAR), survival and SAR by route of passage, evaluation of transportation, straying, age at maturity/age composition, and run size prediction.	Radio tags have been incorporated in evaluating project survival, dam survival, route-specific survival, passage efficiencies, forebay survival and delay, tailrace egress, travel times, avian predation, straying of adult returns, spawning distribution and timing, and adult fallback at dams.
3f	Benefits	Acoustic telemetry is less invasive than other tagging technologies, allows for 2D and 3D tracking, and is detectible in brackish and salt water. Allows for use of run-of-river fish due to small population requirement to get a high level of precision in the study.	Mass marking allows selective catch and release of fish, management of broodstock or natural spawning, and evaluation of supplementation or straying. Adipose fin excision can be done on the smallest juvenile salmon fry, and is easily, immediately, and visually identifiable.	The benefits of CWTs include small size, ease of application, very low tag loss, vast number of codes, low cost, biological compatibility, and minimal impact on survival. The existing CWT system and collaboration with Canada (Pacific Salmon Treaty) are a benefit to the CWT program.	Can be used for both wild and hatchery origin fish. With GSI, the time and place of sampling can be chosen more freely and precisely than with external tagging because it is not dependent on tagging and release programs. In addition, genetic data can be combined with non-genetic data (e.g. scale characteristics and smolt age). Genetic stock structure information can be used to define management units based on genetic similarities between stocks. All fish whose parents are genotyped are tagged.	The advantages of thermal marking include a 100% tagging rate and the ability to tag embryonic or larval fish without having to handle individual fish. There are no known effects on survival or behavior and capital equipment costs are one-time.	PIT tags can be read without killing the host fish and provide opportunities to gain information of migration patterns and rates, and growth rates through lifecycle. The centralized data storage (i.e. PITAGIS) is a strength of the PIT tag system.	Radio tags maintain performance in shallow waters and in turbulent water. Tags have excellent applicability to tributaries, fishways, tailrace, spillway, and reservoirs. Radio tags are especially useful in tracking individuals through acoustically noisy environments.
3c	Limitations	Limitations of technology include: life of transmitter (<30 days), size of tag is currently too big for the smallest subyearlings (and fry) or juvenile lamprey, surgical procedure for implantation, interference from ambient noise (requires higher frequency of signal), and code space.	Limitations are labor time and large capital cost involved to purchase mass marking trailers. Disadvantages also include making the clip unavailable for other competing uses, such as it's long standing use to signify the presence of a coded-wire tag, and redirecting limited financial resources to purchase of marking equipment, mass marking operations, and electronic detection equipment now necessary to detect coded-wire tags.	CWTs are batch marked so cannot track individuals. Sampling is lethal, and tag size limits use on small fry (<40mm). There is a coarse spatial scale of information in the CRB compared to other tagging technologies, and CWT hatchery fish are used as surrogates for wild fish harvest.	Stocks that are genetically similar will not have highly accurate GSI assignment (e.g., fall Chinook salmon from Snake R. and Hanford Reach). Precision and accuracy is dependent on the baseline samples being representative of the genetic characteristics of all the stocks that could contribute to the mixed stock sample. Genetic marking does not provide 'real-time' tracking of fish, and requires that adult broodstock are sampled at the time of spawning and tissue is preserved correctly. Requires huge genotyping workload and standardization among labs.	Limitations include challenges with surface water, absence of an external identifier, lethal mark recovery, power outages, high capital investment, and additional tasks required for busy hatchery managers.	PIT tags are not as effective in estimating project survival and route compared to acoustic and radio tags. Only larger fish are taggable, tags are more expensive than CWT, and there are conflicting results on long-term tag effects.	Radio tag transmission is limited by depth of fish. Poor performance is observed in depths > 10m and in saline waters. Radio telemetry requires an external antenna, and tag life is limited by battery size (can range from days to years). Tag size limits use on small fry (<95mm). Limited code set compared to those available for other tagging technologies.

	FTF Charter Objectives	Acoustic	Adipose Fin Clip	Coded Wire tags	Genetic Markers (PBT/GSI)	Otolith Thermal marks	PIT Tags	Radio tags
3f and 3g	Alternative tagging technology	PIT and acoustic tags can be used for similar measurements (e.g., dam passage survival), but PIT tags do not allow for 2D and 3D tracking of behavior. Acoustic telemetry is detectable in brackish and salt water and has a higher detection range than PIT tags. PIT detections provide backup measurements to confirm passage in instances where acoustic tags fail to be detected.	Adipose fin clips serve as the only visual identification of hatchery-origin fish. The adipose clip imposes little mortality, and less stress than other visual marks. Adipose clipping is fast and cheap compared to other marks, especially since the development of automated equipment.	CWT tags are an alternative source of SAR information to PIT tags. Genetic studies are an alternative estimation of ocean fishery impacts, but are computationally very intensive and take longer to obtain results. The CWT recovery program remains the only method currently available for estimating and monitoring fishery impacts on individual stocks of coho and Chinook salmon when implementing fishing agreements under the PST.	PBT could be used to address similar types of research and management questions as those currently addressed using CWTs. However, genetic marking does allow for non-lethal sampling when recovering tag information as opposed to CWT. PBT tagging would be only method that could address issues associated with relative reproductive success or heritability of specific traits.	The current objective of otolith marks is to manage hatchery broodstock. CWT and PBT are alternative methods to identify hatchery fish. PBT is more expensive to identify hatchery fish (at $40 per fish), while otolith marking is $15 per fish. Otolith marks have relatively high recovery rates in both hatcheries and on spawning grounds.	PIT tags provide SAR data more rapidly than CWT data. PIT tag data is often uploaded automatically to PTAGIS, while CWT data is usually provided to RMIS on an annual basis. Once installed, PIT tags require no handling to transmit data.	Acoustic telemetry can provide similar information concerning project survival, and has similar tag failure rates, mortality due to tagging, number of fish released, and tag "recovery".
3d	Data system for organizing and tracking tag data (release and recovery)	USACE has a contract with the University of Washington to develop an archived database to store/manage all the JSATS information. *JSATS data is currently stored in TAGVIZ (Tag Visualizer) to store spatial and temporal information about the river environment.* *ATLAS (Active Tag-Life-Adjusted Survival) provides survival estimates from acoustic tag data. ATTracker (Active Tag Tracker) offers 3-D acoustic tag tracking.*	A regional data base was developed in the 1960s and 1970s to differentiate between various fin clips on stocks.	PSMFC manages the CWT program system, including registering all the codes that are used in fish each year, by agency. Regional Mark Information System (RMIS) serves as a coordinated coastwide database. RMIS is utilized for international coordination of tagging efforts between the United States and Canada.	Progeny or similar databases for tracking sample and genetic data are available in most PNW genetic labs. IDFG and other agencies are working with PSMFC to develop a Snake River hatchery database that would allow efficient tracking of family groups from spawning to release. A permanent genetic database repository of PBT genotypes is needed to implement PBT across the Columbia River basin.	*The NPAFC hosts an online database, where mark coordinators can enter and audit otolith marks, and from which users can download information and images of marks that have been released and are publicly available.*	PITAGIS serves as a database to store data related to PIT tags. NOAA began to develop this database technology in 1987, and incorporates all species that are PIT-tagged. Canada may be developing a PIT tag database.	Radio telemetry generates very large datasets and millions of records. A long term database for radio telemetry datasets is stored at UI and NMFS.
3d	Data availability	Acoustic telemetry data is not openly shared with others. USACE has a contract with the University of Washington to develop an archived database to store/manage all the JSATS information. Because of the complexity in interpreting acoustic tag data, USACE does not favor open access.	The adipose clip for the objective of selective fishing provides a limited amount of data to model new regulatory constructs and fish behaviors.	Over 40 years of CWT data is available, so there is a large historic database of information. Analysis of CWT takes roughly a week to analyze. The goal at WDFW is to get CWT tag data into RMIS within one year. Data is accessible in various formats and summary reports.	Standardized SNP genotype databases are housed on Progeny software and available upon request. A permanent genetic database repository of SNP genotypes for Columbia Basin GSI is needed.	*The NPAFC hosts an online database, where mark coordinators can enter and audit otolith marks, and from which users can download information and images of marks that have been released.*	PITAGIS serves as a database to store data related to PIT tags. The data is available to everyone and can be accessed using a variety of tools on the website.	The complexity of code definitions and interpretations of detections has made the conversion to an open source database challenging. The majority of coded database data is used by researchers.
3e	Degree of coordination within tagging efforts	*Tags are not compatible across tag detection platforms. VEMCO technologies (used by the Pacific Ocean Shelf Tracking project) and JSATS (incorporated into Basin studies) require unique acoustic receivers.*	Virtually all Coho and spring/summer Chinook raised with the intent of supporting fisheries are adipose fin clipped.	The Regional Mark Processing Center (RMPC) provides essential services throughout the Pacific region to help coordinate regional tagging efforts and fin marking programs.	High among CRITFC and IDFG labs with respect to standardization of genetic marker sets, broodstock sampling and tag recovery projects. Inter-lab (CRITFC/IDFG) SNP standardization and accuracy checks have demonstrated >99.8% genotyping concordance.	The North Pacific Anadromous Fish Commission (NPAFC) designates the unique thermal mark patterns. WDFW assists in coordinating the marking in WA and in OR.	PITAGIS has a steering committee that reviews the metadata and provides input from states and tribes on what PIT data to collect. Regional PIT tag plan is currently being developed.	Evaluation of passage through multiple dams is often coordinated within an agency. Ad hoc coordination is based on radio tag frequency. Data collection at shared detection sites for fixed arrays can be coordinated among researchers.
3e	Degree of coordination among tagging efforts (dual tagging)	Fish are often dual tagged with acoustic and PIT tags. The PIT detections provide backup measurements to confirm passage in instances where acoustic tags fail to be detected.	The presence of a CWT and a fin clip are no longer correlated as a result of changes in mass marking strategies.	CWT recovery infrastructure has been used to collect data for genetic and PIT programs. Currently, the CWT program does not take advantage of the CRB adult and juvenile PIT tag infrastructure.	The CWT recovery platform has been used to collect data for genetic marker programs. Existing infrastructure for both CWT and PIT tag collections also take genetic samples.	The NPAFC workgroup was established to coordinate international application and exchange of information to improve accuracy of mark recognition among scientists and managers.	PIT tags are part of forecast and in season management and supplement other technologies addressing Harvest decisions. The CWT recovery platform has been used to collect data for PIT tag programs.	Radio tag data is used with 3D acoustic telemetry to refine management decisions about dam operations. Tag life is related to size and burst rate, but is often used with PIT tags to improve lifespan analysis, and transportation and straying studies.
3g	Adequacy of geographic coverage	Willamette River, Columbia River, Snake River. Stream passage projects at Cougar and Detroit.	Fin clipping occurs throughout the CRB.	Tagging programs are carried out at over 260 federal, state, tribal, and private hatcheries and rearing facilities on the west coast, including Canada.	SNP baselines with up to 192 markers are in place for steelhead and Chinook salmon in the Columbia River. Coastwide baselines for both species using standardized SNP markers are being developed. Coastwide microsatellite baselines are in place for Chinook and coho salmon. Currently, only the Snake River basin is under a PBT sampling/genotyping program for all hatchery steelhead and Chinook salmon stocks.	Thermal marking is currently in select hatcheries throughout the CRB, including several Washington and Oregon hatcheries.	*PIT tagging activities occur on or at more than 550 rivers and streams, dams, traps, and hatchery rearing and release facilities throughout the Basin within the range of anadromous salmon and steelhead, including the Okanogan River in British Columbia above Osoyoos Lake.*	Scale of investigation can range from meso-scale (10m-10km) to large-scale evaluations (10-1000s km). Currently, there are monitoring arrays at 4 lower Columbia dams, 4 Snake River dams, and over 147 mobile tracking receivers.
3g	Completeness of life cycle tracking	Full life cycle tracking is not possible. The lifespan of acoustic tags is typically just over 3-months. Therefore, only discrete periods of time can be monitored.	Full life cycle tracking is not possible. The main purpose of adipose fin clipping is to provide visual identification for selective fisheries.	Tags provide information of fish origin and harvest or recovery; however, they can't provide information on the path taken by the fish between two points.	Complete for the life of the fish.	Marks can be used to identify fish migration between different environments. However mark analysis only occurs at the end of the life cycle.	Complete lifecycle tracking; smolt abundance, freshwater productivity, juvenile migration rate, SAR, adult spawner migration.	Complete life cycle tracking is not possible. Tag life ranges from days to years.
3g	Span of species diversity	Broad applicability among aquatic animals, though variability of location, cost of detectors and tag life and range is significant.	Fin excision can be done on the smallest juvenile fry and is not species-specific.	Emphasis of the program is on tagging Chinook and coho, with smaller numbers of steelhead and only a few sockeye tagged each year.	In the Columbia river basin genetic markers and baselines are available for Chinook salmon, steelhead, sockeye, and coho.	Otolith thermal marks are applied to all five Pacific salmon species, Atlantic salmon, Kokanee, cutthroat, and steelhead.	PIT technology used for Chinook, steelhead, sturgeon, and bull trout. Current studies aim to identify a suitable PIT tag for juvenile lamprey.	Radio tags can be used to study all species of adult salmonids, adult Pacific lamprey, and juvenile salmonids within the freshwater portions of the Basin.

	FTF Charter Objectives	Acoustic	Adipose Fin Clip	Coded Wire tags	Genetic Markers (PBT/GSI)	Otolith Thermal marks	PIT Tags	Radio tags
3b	Technology costs	JSATS costs for tags is currently around $200 per tag with a goal to get tag price down to around $100. JSATS receivers: $8,000 to $9,000 each, $19,000 each for cable arrays. The studies follow a standard protocol. Full program cost for Lower Columbia survival studies is about $13 million per year.	Costs usually run between $30-40 per thousand fish marked. Infrastructure costs require investment in marking trailers which have a high capital cost but can be used in many locations and over several years. Marking trailers can have both automated and manual mark lines.	Tags are roughly 17 cents apiece. Total CRB CWT recovery program costs is over $6 million.	No direct tagging costs, but reference genetic baselines are needed for GSI. Genotyping costs will vary depending on the lab and type and numbers of genetic markers used. Generally most labs charge $35-$55/sample.	Thermal marking requirements include an insulated box (~$6,000) with 3 portable chillers (~$3,200 each), inline chiller, moist air incubator systems (MAIS), "desiccation", and two water sources. Total cost ~$10,000. Average costs are: $4 per juvenile/fry fish; $12 per adult fish to read and section otolith; $15 per Chinook adult fish to read and section otolith.	Cost of PIT tagging, including the tagging, data management, and analysis, averages out to $1.60 per PIT-tagged fish. In a Wind River PIT tag study, additional infrastructure requirements included 2 handheld readers ($6K), and instream detectors ($10K-$55K).	Tag costs range between $200-300 per tag. Basic mobile tracking receivers are between $1,000-2,500. For hydrophones, costs can range about $10,000 +- $2,000. Other equipment required includes antennas, cable, and line amplifiers. An estimate of direct cost is $100K for a small-scale study, and up to $600-700K for a large reach-scale study in the mainstem.
3c	Confidence interval driving study design and population size to be marked/tagged	Confidence interval for the USACE survival studies is 95% +/- 2 to 3%; Chelan and Grant County PUDs have 2.5% standard error.	N/A	95% confidence interval.	Stock resolution and accuracy of mark assignments depends on the underlying genetic structure of the species, the accuracy to which allele frequencies are estimated in populations and reporting groups, and the number and variation of the loci used.	Low error rate in detecting marks. Accuracy in thermal marking patterns is improved by taking a subsample once fish are marked to verify proper mark application.	Detection probability at BON is about 98%. NOAA estuary PIT trawl's detection efficiency is only about 2%.	Confidence interval for detection on riverine gates is 90-98% and 95-100% along mainstem passage routes.
3c	Tag loss (shedding) rate	Tag loss was evaluated in 2007 and 2008 and did not indicate any significant loss of acoustic tags.	N/A	Retention rate is typically 99% on fish tagged by machine.	N/A	There is a 100% tagging rate with an identical mark for hatchery fish.	1.2% is the average PIT tag loss over nine years in the Rapid River Hatchery group.	Known radio tag loss rate is between 2.2-4% (Keefer et al. 2004).
3c	Tag failure rate	JSATS tag failure rate generally less than 1%.	N/A	N/A	Approximately 1-5% of samples fail genotyping due to poor storage of tissue.	Embryonic, larval, or adult fish are permanently marked.	PIT tag failure is estimated at less than 1%.	Unaccounted tag loss in the mainstem was 12%, and includes unreported harvest, death (including tag effects), and tag failure.
3c	Increased mortality due to tagging	Estimates of tagging mortality vary greatly. Research indicates tagging mortality ranges from 3-33% across all tagging types. One study indicated a small (0-4.5%), and decreasing with shrinking tag size.	There is about a 2-3% mortality rate of mass marked fish.	Very low, less than 1%.	N/A	There is no known effect on survival or behavior to tagged fish.	Estimates of tagging mortality vary greatly. Research indicates tagging mortality ranges from 3-33% across all tagging types. One study specific to PIT tagging indicated an average 5 year mortality of 10%.	Estimates of tagging mortality vary greatly. Research indicates tagging mortality ranges from 3-33% across all tagging types. Mortality is similar to acoustic telemetry in suitable environments.