State of Washington Department of Fish and Wildlife

Technical REPORT
No. FPT 11-02

Summary of the Coastal Black Rockfish Tagging Program 1981-2008

Farron Wallace, Tien-Shui Tsou, Yuk Wing Cheng, and Lorna Wargo

November 2010

Table of Contents

Acknowledgements

There have been numerous staff and thousands of project volunteers that have contributed their time to the black rockfish tagging over the years. We would like to first acknowledge all of the volunteers for their dedication and commitment to this resource that made this program a success. Without their participation we would not have been able to conduct this program. There has also been a number of staff that has dedicated countless hours on the water and developing project designs including: Bill Clark, Brian Culver, Jack Tagart, Han Lin Lai, Annette Hoffman, Dan Ayers, Travis Haring, Cameron Andrews and Eric Eisenhardt.

Executive Summary

Black rockfish (*Sebastes melanops*) is an important natural resource to the coastal recreational fisheries that coastal communities rely upon for a vital economy. The economic value in Washington State in 2006 for saltwater fish other than salmon and steelhead was $11.2 million (TCW Economics, 2008). Black rockfish accounts for 80% of the annual catch from bottomfish targeting angler trips. Due to the importance of this resource, the Washington Department of Fish and Wildlife and the coastal recreational charter boat fleets have been collaborating on tagging projects for the conservation of black rockfish and other coastal groundfish species. Information collected through these projects has been incorporated into stock assessments for evaluating black rockfish stock status and supporting Washington's and Pacific Fishery Management Council's (PFMC) management needs. This report compiles nearly 30 years of black rockfish tagging studies, and is intended to serve as a key reference document describing changes in research objectives and methods that evolved over time as research built upon earlier studies.

In Washington, the first black rockfish tagging project began in 1981. Since then, there were several major changes to objectives and scope of the project. These changes were reflected in the distribution of tagging effort over time. The effort distribution and its geographical extent for tag releases were based on salmon management Punch Card Areas (PCA 1-4) or a finer scale division of these areas (Figure E-1). Between 1981 and 1985, black rockfish were tagged and released in selected areas located within the recreational fishing areas off the ports of Ilwaco (PCA 1), Westport (PCA 2) and Neah Bay (PCA 3) aboard both Department and recreational charter vessels. Between 1986 and 1990, an effort was made to allocate tagging effort in a random fashion throughout coastal waters fished by the Washington recreational fleet. PCAs were divided among six tag areas each with three sub-areas (a, b and c) and the amount of time fishing (effort) was equally allocated among

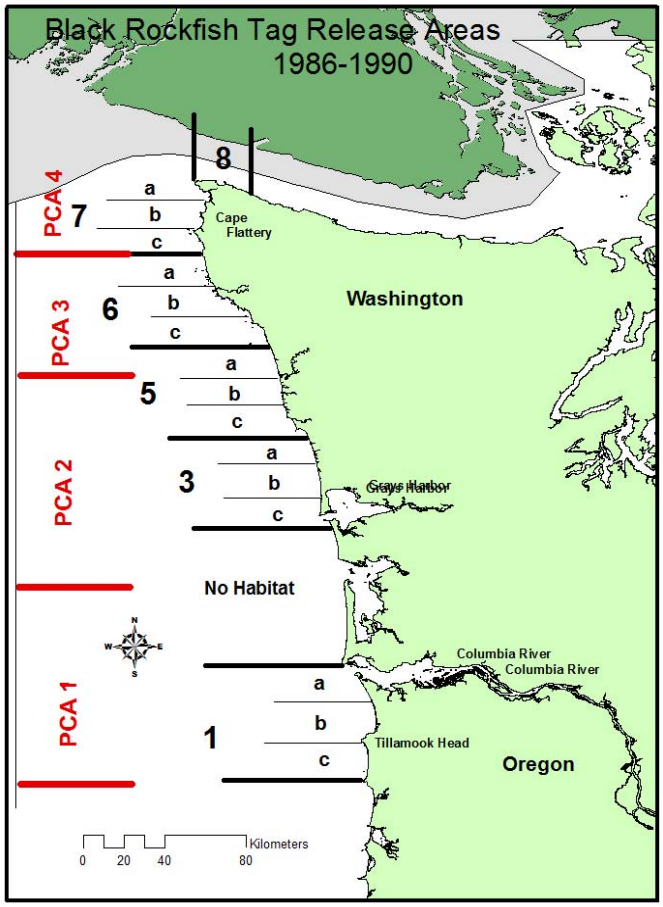

Figure E-1. Geographical boundaries of salmon management Punch Card Areas (PCA) and black rockfish tagging areas.

each tag sub-area. No effort was expended between the mouth of the Columbia River and Ledbetter Point, Washington, due to the lack of rocky habitat. Beginning in 1998, the study area was constrained to the central Washington coast in areas within the operation range of the Westport charter fleet (tag sub-area 3a, 3b, 3c and 5c). Between 1998 and 2000, distribution of tagging effort was based on the knowledge of the charter vessel captain and tagging crew to distribute tags "proportionally" to the resource in this area. In order to formalize methods and provide greater consistency in effort distribution through time, rocky habitat was identified and geo-referenced. Beginning in 2001, tagging effort was weighted proportionately and distributed relative to the amount of rocky habitat found in each 2-degree latitudinal block.

Tag release and recovery statistics reflected changes in research goals, objectives, and funding, which affected the number of releases and spatial distribution of the release sites (Table E-1). Between 1981 and 1990, a total of 52,042 fish were tagged with three-inch

Table E-1. Number of tag releases and tag recoveries by salmon management Punch Card Area (PCA) and tag recovery method employed.

	Number of tag releases by Punch Card Area						Number of tag recoveries by Punch Card Area					
Year	1	2	3	4	Total	Recovery Method	1	2	3	4	Other	Total
1981		4,739			4,739	Voluntary Only	2	17				19
1982		2,171		370	2,541		23	36				59
1983	1,199	109		725	2,033		37	57		8		102
1984				674	674		30	24		3	1	58
1985	1,283	2,409		1,148	4,840		26	120		41	3	190
1986	784	2,273	1,908	894	5,859	Voluntary / Sampling	24	217	5	34		280
1987	1,075	1,357	1,939	931	5,302		18	178	11	25		232
1988	1,085	2,726	2,739	1,348	7,898		21	156	6	33		216
1989	1,414	2,440	2,911	2,443	9,208		23	116	15	45		199
1990	1,038	2,444	3,602	1,864	8,948		31	143	23	22	1	220
1991							12	126	11	29	2	180
1992							10	52	17	29	5	113
1993						Voluntary Only	4	34	17	7		62
1994							2	17	2	1	1	23
1995							1	4	1			6
1996								2				2
1997								1				1
1998		2,628			2,628	Catch Sampling Only		14				14
1999		3,479			3,479			76				76
2000		2,789			2,789			344				344
2001		3,210			3,210			229				229
2002		4,089			4,089			372				372
2003		6,753			6,753			579				579
2004		6,155			6,155			277				277
2005		3,950			3,950			292				292
2006		6,289			6,289			468				468
2007		5,704			5,704			832				832
Total	7,878	65,714	13,099	10,397	97,088		264	4,783	108	277	13	5,445

Floy FD-68B T-end spaghetti anchor tag of which 1,962 were recovered. In the early part of the study (1981-1985), tag recoveries were entirely dependent on voluntary returns. A catch sampling program was initiated in 1986 and continued through 1992 in an effort to recover tagged black rockfish from both the recreational and commercial fishery. Tagged black rockfish were also recovered through voluntary returns. Although the catch sampling program ended in 1992, voluntary returns continued through 1997. Beginning in 1998, fish were internally tagged with Code Wire Tags (CWT) or Passive Integrated Transponder (PIT) tags. A catch sampling program was again initiated to sample recreational catch for tags caught from the central Washington coast. Because these tags are not visible, there are no voluntary recoveries.

Tagged black rockfish have been part of the recreational catch for nearly three decades with some tagged fish recovered after more than 15 years at large. As a consequence of tag loss, fishing, and natural mortality, and immigration and emigration tags from all release groups show a significant declining recovery rate through time (Table E-2). Although, the largest proportion of tag recoveries occurred near the area of release, data clearly show that tag recoveries could occur at extended distances from the release area. However, there was a declining tag recovery trend with increasing distance from release area.

Table E-2. Number of tags recovered by release and recovery year.

Release	Year of recovery																											
Year	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	Total
Unknown[1]						1					19	6																26
1981	19	53	50	32	8	8	9	6	6	4	3																	198
1982		6	28	6	2	2		1	1			2																48
1983			24	17	13	3	2	3	1	1																		64
1984				3	3	1	2	1																				10
1985					164	146	40	25	15	8	2	1																401
1986						119	84	52	20	12	7	2		1														297
1987							95	71	33	18	5	8	5															235
1988								57	79	20	21	10	5	3	1	1												197
1989									44	65	57	25	17	3	3													214
1990										92	66	59	35	16	2	1	1											272
1998																		14	33	79	34	16	32	4	7	5	10	234
1999																			43	135	59	71	54	12	17	15	16	422
2000																				130	69	80	74	29	14	15	39	450
2001																					67	62	77	40	37	22	27	332
2002																						143	148	54	33	41	49	468
2003																							194	74	54	49	115	486
2004																								64	75	100	117	356
2005																									55	76	130	261
2006																										145	159	304
2007																											170	170
	19	59	102	58	190	280	232	216	199	220	180	113	62	23	6	2	1	14	76	344	229	372	579	277	292	468	832	5445

Although tagging objectives and methods have varied through time, tagging information has provided key information to determine population dynamics for the black rockfish stock located between Cape Falcon, Oregon, and Cape Flattery, Washington. Continuation of a data collection program that measures biomass or population trends

such as the current tagging program is essential for monitoring the health of this important coastal resource and for supporting future stock assessments of this species. Much consideration has been taken to ensure proper evaluation of these data. Importantly, changes in spatial and temporal distribution of tag releases and the spatial-temporal changes in the fisheries need to be considered for proper interpretation of tag recovery rates and movement patterns.

The black rockfish tagging program was last reviewed in 2008 based on program costs and its efficacy in providing information needed for sustainable ecosystem management. An overall conclusion was that there was an urgent need to develop a long-term monitoring program with greater spatial extent for multiple fish species to support Washington fisheries management. The review recommended the use of fixed stations for capture and recapture of all fish species along the entire Washington coast using PIT tags. The experiment will be conducted in spring and fall, before and after the main fishing season. The revised tagging program will provide more unbiased biological information on spatial movement and growth for multiple fish species commonly caught in the recreational fishery. It will also improve validity and reliability of estimates on abundance trends. The recommendations and changes will be field tested beginning in fall 2010. Current protocols for tag release and recovery will continue.

1. Introduction

Black rockfish (*Sebastes melanops*) are widely distributed along the Pacific coast from central California to the Gulf of Alaska inhabiting nearshore areas at bottom depths of less than 50 fathoms (Miller and Lea, 1972; Love et al, 2002). Adults are schooling and associated with irregular, rocky bottom or other underwater structures, though at times may be found actively feeding near the surface.

Recreational and commercial fishers have harvested, both incidentally and in a directed manner, black rockfish in nearshore areas off the Washington coast and in Puget Sound since the early 1940s. Commercial fisheries include salmon and bottomfish troll, jig, and groundfish trawl. The recreational fishery is comprised of charter and private boat operations. Due to increasingly restrictive regulations, black rockfish landings have steadily declined for commercial fisheries since the mid-1980s. In recent years, nearly all black rockfish are harvested in recreational fisheries. Recreational black rockfish landings peaked in the late 1980s and declined slightly in the 1990s to present day levels.

This document compiles nearly 30 years of black rockfish tagging research off the Washington coast by the Washington Department of Fish and Wildlife (Department). This report is intended to document past and present tagging methods, summarize results describing movement and catch rates, and provide an evaluation of current methodology. Much of the data collected from this research has been instrumental in developing stock assessment models for the presumed coastal black rockfish stock found between Cape Falcon, Oregon, and Cape Flattery, Washington.

2. Tag-and-release Experiments

Black rockfish have been a focus of coastal marine fish research for the Department since 1981. This interest was due to the increasing importance of this species in the late 1970s and early 1980s as recreational salmon fishery opportunities declined and fishers began targeting other species, such as rockfish. Since the establishment of the tagging program in 1981, research objectives and methods have evolved building on results of earlier studies and depending on available funds. Tagging methods and results are separated into four time periods (1981-1984, 1985, 1986-1994, 1998-2008) that coincide with significant methodological changes that were made to improve research and to meet changing objectives. Details of these changes are documented below.

2.1 Methods

2.1.1 1981-1984 Period

OBJECTIVES

Prior to 1981, little was known regarding the life history of the black rockfish. Consequently, early tagging work concentrated on gathering biological information, such as movement and growth. Tagging work began in 1981 as a cooperative project between the Department and the Washington State Charter Boat Association (WSCBA).

EFFORT/TAG DISTRIBUTION

Between 1981 and 1984, black rockfish were tagged in selected areas located within the usual fishing grounds of the Westport, Ilwaco and Neah Bay recreational fleet (Figure 1) aboard both Department and recreational charter vessels. Tagging was done primarily using the Department's vessel the *G.H. Corliss*. However, several smaller research vessels belong to the University of Washington (UW) were also used as tagging platforms in 1984. Personnel from the UW Fisheries Cooperative Research Unit participated in the 1984 efforts near Neah Bay to collect information for a Master's thesis (Kuzis, 1984).

TAGGING METHODS

The tagging crew consisted of two or three Department staff and a group of eight to fifteen volunteer anglers. Fish were caught using rod and reel rigged with one to three single hook jigs (artificial worms and shrimp flies) per line. Once caught, fish were tagged with a three-inch Floy FD-68B T-end spaghetti anchor tag inserted into the musculature between the dorsal fin pterygiophores with a Dennison tagging gun. All fish were tagged on the left side of the dorsal fin and approximately 6% of the fish were double-tagged with a second Floy tag on the right side. Recovery information of the double-tagged fish was used to examine tag loss rates. During tagging, fish were inspected for physical condition, measured for fork length to the nearest (cm), tagged, and immediately released. To avoid problems associated with barotrauma, only fish found near the surface were targeted for tagging. Any fish suffering from severe barotrauma or other physical trauma such as gill or eye damage, or bleeding, was not tagged. To evaluate short term tagging mortality and tag loss, several small groups of fish were tagged and retained in open ocean aquaria and some held in a net pen. Tag loss and mortality was tallied on a daily bases.

To verify age and growth of black rockfish, approximately 20% of the tagged fish were also injected interperitonealy with oxytetracycline hydrochloride (OTC) on an opportunistic basis and not by set schedule or rate. OTC was injected at a dosage rate of 50mg/kg body weight (Weber and Ridgeway 1962; Kobayashi et al., 1964). OTC is incorporated into bony tissue leaving a check on the fish's otolith that is visible under ultraviolet light. Comparison of otolith growth subsequent to the OTC check with the time at liberty provides insight into the reliability of ageing techniques based on annual growth increments. These increments were enumerated by applying break-and-burn techniques on the otoliths. Since the OTC mark attenuates when exposed to light, recovered sagittal otoliths were stored in film containers until processed. Before ageing, otoliths were broken across the focus then photographed under ultraviolet light to identify and locate the mark. Otoliths were then burned to enhance the contrast between wide opaque and narrow translucent growth bands and then re-photographed under the same magnification (10x-80x) with white light (after Leaman and Nagtegal 1987). Annuli subsequent to the OTC mark were then enumerated and compared to years at liberty.

A holding experiment was also conducted on OTC injected fish in 1982. Five tagged black rockfish collected while tagging were placed in an open ocean circulation aquarium. Fish were allowed to acclimate for one week, and were then injected with

OTC at the same dosage rate used in the tagging study. Four of these fish were held for 60 days and one was held for two years before being sacrificed to examine otoliths for signs of OTC deposition.

TAG RECOVERY METHODS

All tag recovery information is based upon volunteer return of tags by fishers. As an incentive to fishers to return tagged fish, the Department offered a $2.00 reward for each returned tag plus a randomly assigned bonus reward of $10.00 for 5% of the released tags and $50.00 for 1% of the released tags. The study was well publicized and posters were placed throughout coastal ports harvesting black rockfish. In addition, the WSCBA began promoting recreational fishing for groundfish and began conducting an annual "Snapper Derby" in 1981. A $50.00 reward was offered for the return of any tagged fish caught by a derby ticket holder.

2.1.2 1985

OBJECTIVES

Tagging work conducted in 1985 was again a cooperative project between the Department, WSCBA, and the UW. The primary focus of this research was a pilot study to evaluate potential mixing rates of black rockfish found inhabiting the southern, central, and northern waters off the Washington coast.

EFFORT/TAG DISTRIBUTION

Tagging methods were the same as those used in the previous study period (1981-1984). An effort was made to release all fish within a two-week period at the beginning of the sport fishing season. However, weather and ocean conditions prevented this and all fish were eventually released during a one month period between April 22nd and May 21st. Tagging effort was expanded to include sites in coastal waters outside the ports of Ilwaco, Neah Bay, andWestport (Figure 2).

TAG RECOVERY METHODS

Department monetary incentives for tag returns continued unchanged in 1985. However, the recreation charter boat Industry operating out of the ports of Neah Bay and Ilwaco also began participating in the "Snapper Derby".

2.1.3 1986-1994 Period

OBJECTIVE

A major restructuring of the tagging program began in 1986 through increased federal funding from the Dingle-Johnson/Wallop-Breaux (DJ/WB) program. The changes included an increase in the geographic scope to cover coastal waters North of Cape Falcon, Oregon, to Cape Flattery, Washington, a more complete and detailed statewide tag recovery program, and a revised experimental design to meet assumptions and requirements under a Seber Jolly model for estimating population abundance. In addition, biological samples (length, age, sex and maturity) were collected, interview data were taken, and catch was sampled for species composition and tagged fish. The

WSCBA continued to contribute vessels by providing 15 vessel days to support tagging operations.

EFFORT/TAG DISTRIBUTION

In 1986 and 1987, an effort was made to allocate tagging effort in a random fashion throughout coastal waters between Cape Falcon, Oregon, and Cape Flattery, Washington. The coast was divided into eight areas which were further subdivided equally into three sub- areas a, b or c (Table 1 and Figure 3). No effort was expended between Columbia River and Ledbetter Point, Washington, due to the lack of rocky habitat. The amount of time fishing (effort) was equally allocated among each sub-area, and a unit of effort was defined as ½-vessel-day. An attempt was made to randomly select target locations for tagging in each sub-area from a list of previously identified "hot-spots" with high catch rates. If other locations were found in-transit to the selected site, these locations would be fished prior to the selected site. In areas for which no fishable locations were previously known, a random acoustical search of likely habitat was conducted until fish were encountered. No more than ½ hour was spent at any location that failed to produce any fish. At the conclusion of ½ day fishing, the vessel moved to the next sub-area. The number of lines fished, total hours fished and total catch was recorded for each fishing location.

In 1988 and 1990, tagging effort was restricted to rocky habitat that was loosely defined using NOAA charts, known fishing areas, and hydrocoustic information gained from a black rockfish hydrocoustic study (Boettner, 1992). This reduced overall vessel costs by reducing search effort in areas that had been unproductive in earlier years. A total of 21 days at sea were distributed among Areas (1-8 and sub-areas; Figure 3) during these years. Any days cancelled due to weather or other factors were re-scheduled for the next trip.

TAGGING METHODS

As in prior years, fish were tagged with a three-inch Floy FD-68B T-end spaghetti anchor tag inserted into the dorsal musculature between dorsal fin pterygiophores. Approximately every 10^{th} fish was double-tagged to examine tag-shedding rates and, as in previous tagging studies, only those fish not suffering from barotraumas or hook injury were tagged. The release period continued through 1990 and tags were recovered through 1994, after which returns were rare.

Although the Department's patrol/research vessel (H.G. Corliss) was the primary tagging platform during this time period, a number of private charter vessels continued to participate in the tag release program through 1986. However, use of these vessels proved problematic since many of the charter vessels participating in the release of tagged fish began targeting release sites following tagging in the hopes of providing customers a chance to catch a "money fish." Some charter offices began to advertise that their captains knew where to find the tagged fish. Beginning in 1987, only the Department vessel was used in tag release efforts. As in earlier studies, a typical tag-release trip included a 2-3 person tagging crew and 8-15 volunteers that fished using rod and reel with one to three jigs per hook.

TAG RECOVERY METHODS

This study was well publicized and posters were placed throughout coastal ports harvesting black rockfish. Tag recovery information relied on voluntary tag returns from the fishery and from commercial and recreation catch sampled in the port of landing. The Department offered a $10.00 cash reward as an incentive to fishermen to return tagged fish. In addition to this, the WSCBA conducted its annual "Snapper Derby" offering another $15.00 for the return of a tagged fish caught by a derby ticket holder. Various charter boat offices paid rewards directly to fishermen catching a tagged fish the same day of capture and the Department reimbursed charter boat offices at a later date.

2.1.4 1998-2008 Period

Due to costs associated with a coast wide study and declining funds, the study area was confined to coastal waters off the central Washington coast between 46^0 54' N. latitude (just south of Grays Harbor) to 47^0 28' N. latitude (Sea Lion Rock just north of Cape Elizabeth). This area represents the primary fishing grounds of the coastal recreational groundfish fishery for black rockfish and catches in this area account for approximately 75% of total annual Washington catch. Nearly all of the black rockfish from this area is harvested by the recreational charter boat industry operating out of Westport.

OBJECTIVES

After a four year hiatus, the black rockfish tagging program was re-initiated in April, 1998. Methods were significantly changed to minimize tag loss and address assumptions on non-reporting rates. The overall objective of this program was to produce estimates of abundance, growth, survival, and mortality for the portion of the black rockfish stock found in coastal waters off the central Washington coast between Grays Harbor and Sea Lion Rock (2 km North of Cape Elizabeth, Washington). The focus of this study was to inform the coastal black rockfish population dynamics model on abundance trend. These data are assumed to represent the overall population trend for the presumed stock residing in waters found between Cape Falcon and Cape Flattery.

EFFORT/TAG DISTRIBUTION

Rocky habitat and associated black rockfish are not evenly distributed throughout the study area. This presented a unique problem for distributing tag release effort uniformly across the space inhabited by the stock. One of the fundamental assumptions of this tagging experiment is that every animal in the population, whether tagged or un-tagged, has the same probability of capture. Tagging studies generally attempt to meet this assumption by evenly distributing tag effort throughout the study area. Because of the patchy distribution of habitat (and fish) in our study area, knowledge of this distribution is required. An even distribution of tag effort across all areas would disproportionately over-sample fish in strata with little habitat and under-sample fish in strata with dense rocky habitat. In an effort to quantify the distribution of rocky reefs (presumed black rockfish habitats) the study area was divided into seventeen 2^o latitudinal blocks. Known locations of rocky reefs identified from hydroacoustic data (Bentnor, 1990) and from previous tagging studies were geo-referenced. The weighted proportion of habitat in

each 2^{o} latitudinal block was then used to distribute total tagging effort for any given year (Figure 4) beginning in 2001. Prior to 2001 an attempt was made to distribute effort among all known areas of black rockfish abundance using local knowledge of the skipper and crew, but there was no formal attempt to quantify the effort distribution and was therefore haphazard.

The number of rocky reefs in each block was assumed to be proportional to total black rockfish habitat within the study area. To ensure that every fish in the study area had an equal probability of being tagged, tagging effort was then distributed throughout the study area in relative proportion of presumed habitat (Table 2).

TAGGING METHODS

During this period, fish were double tagged with either Coded Wire Tags (CWT) or Passive Integration Transponder (PIT) tags. Beginning in 1998, nearly all fish were double tagged with a single CWT tag in both the left and right cheek muscles located in the center of the operculum. The CWT tags were marked to allow for individual fish identification. In 2004, approximately one-third of the fish were tagged with a PIT-tag in the throat patch with or without a single CWT in the cheek and the remaining fish were double tagged with CWT as in previous years. In 2005 and 2006, nearly all fish were double tagged with a PIT in the throat patch and a single CWT in the cheek. Beginning in 2007, all fish were double tagged with a single CWT in the left and right cheek muscle.

In addition, holding experiments were conducted to validate assumptions about tag loss and tagging related mortality. The estimated tag loss rates from double tagged fish were used to adjust the number of expected tag returns coming from the fishery.

TAG RECOVERY METHODS.

In 1998, a catch sampling program was initiated to recover tagged fish from the recreational charter boat fishery operating out of Westport, Washington. This eliminated the possible bias associated with non-reporting of tagged fish. The tag recovery operation relied upon a cooperative effort between the Department and the recreational fishing industry to maintain a high sampling rate of landed fish. At the end of a fishing day, recreational charter vessels voluntarily left fish carcasses at the dock for tag screening and reported the area in which they were fishing that day. The carcasses were first passed through an R8000 CWT tag detector. If detections were positive, the fish were then checked for a PIT tag using a PIT tag detector from Destron. The R8000 was calibrated throughout each day to ensure the highest level of CWT detection. Data on numbers of fish sampled, total number of positive detections, and number of PIT tags recovered were tallied daily. Information on fish length and sex was recorded for each fish that tested positive for a possible tag. Heads were removed and labeled, CWT were removed and identified at a later date, and otoliths were removed for ageing. Several experiments were also conducted to ensure detector reliability and to evaluate the PIT tags for future tagging studies.

2.2 Results

Though the program went through four periods as described above, results are presented in two time periods corresponding to the spaghetti tag release time period (1981-1997) and then the CWT/PIT tag time period (1998-2007) of the tagging program.

2.2.1 Tag release and effort statistics

1981-1997

Throughout this time period, there were considerable changes in research goals, objectives, and funding. Consequently, statistics of tag release and recovery reflect these changes in both number of releases and in spatial distribution of the tagged fish releases. The last year of tag release during this period is 1990, while tags were recovered and returned until 1997. A total of 52,042 tagged fish were released using different types of tags (Table 3) and in different areas (Table 4). More than 3,000 fish were double tagged throughout the early tagging time period (Table 3) in an effort to estimate Floy spaghetti tag loss. In addition, nearly 2,000 fish were also injected with OTC between 1981 and 1983 to validate aging techniques. The number of tag releases and the spatial distribution of tags increased substantially beginning in 1986 (Table 4).

In 1986, an attempt was made to distribute fishing effort (half vessel days) evenly among all tagging areas. Unfortunately, it was not possible to evaluate how well this was accomplished because only fishing effort (not search time) was recorded. Angler hours and number of fish released varied considerably between tagging areas. The observed differences mostly reflect changes in habitat and fish distribution rather than fishing effort (Tables 5 and 6).

1998-2008

During this second period, nearly all fish were doubled tagged with CWTs or a single PIT and CWT (Table 7) because the cost of double tagging with CWTs was minimal and it did not substantially slow the tagging process. Beginning in 2001, fishing effort (angler hours) was distributed proportionally to the estimated amount of habitat in each 2^{o} latitude block. This resulted in a reasonably consistent spatial distribution of relative fishing effort between years and within area (Table 8 and Figure 5). Spatial distribution of the number of tags was somewhat variable among areas and between years, but without trend (Table 9 and Figure 6). This was likely due to weather and water conditions that affected catch rates in the same area in different years. Although the relative proportion of total fishing time in each area was consistent since 2001, the total time spent fishing (angler hours) across all areas varied dependent upon funding that controlled the number of days we could employ a charter vessel and weather (Table 10). Generally, it appears that the overall catch per unit of effort (CPUE = number of releases/angler hours) across tag areas and among years has shown an increasing trend since 2001 (Table 11). Among the seventeen tagging strata, six of them were sampled at least nine out of the ten years. The annual average CPUEs of these strata are higher than the average CPUE from all area combined (Table 12 compared to Table 11). The observed variability in CPUE within an area among years could be influenced by weather and tidal conditions at the time of tagging. For example, during bad weather days it

would be much more difficult to remain in high catch rate locales and fish may not be as apt to bite. It is assumed these differences would be averaged out across areas on an annual basis and therefore changes in CPUE across time should reflect changes in abundance. The same assumption is necessary for estimating abundance or developing a population trend index.

2.2.2 Catch sample statistics

1981-1994

Over 1.5 million landed black rockfish were sampled for tags coastwide during spring, summer and fall between 1986 and 1992 at five ports – Ilwaco, Westport, La Push, Neah Bay, and Sekiu. The largest numbers of fish sampled occurred during August (Table 13). The recreational bottomfish fishery contributed over 85% of the total number of black rockfish sampled for tags by fishery (Table 14). Since most of the recreational catch came from punch card area 2 (PCA 2), the largest number of black rockfish sampled for tags also came from this area (Table 15 - 17). Most of the sampled catch from the commercial fishery came from the hand-line-jig fishery, which was largely concentrated in northern Washington areas operating in PCA 3 and PCA 4 (Table 18). There were considerable, although sporadic catches of black rockfish taken by the trawl fishery on a shipwreck site (the "Wheatship") near the mouth of the Columbia River. Much of this catch was not sampled. A large proportion of the overall sport catch was sampled for tags and a much smaller proportion of the commercial catch was sampled by port samplers (Tables 19-20).

1998-2008

Between 1998 and 2008 nearly 2,000 days were spent sampling over 700,000 landed black rockfish for tags during spring and summer months (Table 21) at Westport. The greatest number of fish sampled was during the peak of the sport fishery in June, July and August (Table 22). All of the sampled catch comes from PCA 2 where approximately 80% of the total recreational catch of black rockfish is taken (Table 23). A large portion of the recreational black rockfish catch in PCA 2 was sampled for tags on an annual basis (Table 24).

2.2.3 Tag recovery statistics

1981-1994

Prior to 1986 all recovered tags were returned voluntarily. Between 1986 and 1992 tags were recovered from both the catch sampling program and through voluntary returns. During this period, a total of 1,962 tags were recovered, of which 66% were recovered from PCA 2 (Table 25). Approximately 35% (679) of the recovered tags were recovered from catch samples, with most of them from PCA 2 (Table 26). The remaining (65%) were voluntarily returned by recreational and commercial fishers. Overall, nearly 75% of the tags were recovered from the sport fishery and 25% from commercial sectors. The

trawl fishery caught 188 tagged fish between 1981 and 1985 and the jig fishery caught 249 tagged fish between 1985 and 1997 (Table 27).

The proportion of tags recovered by year and PCA varied across years, but remained relatively high in PCA2, where the majority of catch was sampled (Table 28). The tag recovery rate (sampled tags/sampled catch) from sampled catch was exceptionally variable in PCA1 and PCA3 (Table 29 and Figure 7). Comparison of tag recovery rates from sampled catch across years and areas show comparable rates of recovery (between 0.05 and 0.10). Tag recovery rates from total landed catch (volunteered + sampled tags divided by total catch) was fairly consistent across time for all PCAs except PCA3 (Table 30 and Figure 8). Comparison of tag recovery rates between sampled and total catch by PCA and year showed that tag recovery rates from sampled catch were lower than those from total catch for all PCAs with the exception of PCA2, even though a substantial proportion of the catch was sampled for tags in all PCAs (Figure 9). This may indicate that fishers recovered tags from their catch prior to mark sample recovery and subsequently returned them to the Department at a later date for reward. This trend can also be seen in PCA2, but to a lesser degree. A comparison of percent of sampled catch by year and percent of total tags recovered from the commercial fishery indicates a variable rate of recovery from the commercial fishery across years (Figure 10).

Comparing the number of tags recovered by release and recovery year clearly shows a declining catch of tagged fish by release group through time from both total and sampled catch (Tables 31 - 33). This is a consequence of tag loss, fishing and natural mortality, and immigration and emigration. Although the largest proportion of tag recoveries were recovered from the area of release, data clearly show that tag recoveries can occur at fairly extended distances from the release area, but with declining recoveries as distance from release area increases (Table 34 and Figure 11).

1998-2008

During this period, tags were only released out of the Westport area and were recovered only through catch sampling at Westport. Nearly 4,000 tags were recovered from all tag types and areas since 1998 (Table 35). The recovery showed a seasonal pattern over the period of this study (Table 36 and 37), which reflected the operating pattern of the recreational fishery during calm weather between June and early September. The number of tags recovered by month and year indicates a declining trend for August and an increasing trend for May between 1998 and 2008. Given that our catch sampling efforts were relatively constant over time (Table 21), we believe this was due to greater salmon fishing opportunities in August, and fishers targeting salmon rather than bottomfish. This may have also resulted in declining capture rates in August in most recent years (Figure 12). The increasing trend in May results from increasing recreational bottomfish effort during early spring than in earlier years. The tag-recovery rates varied among months and between years and rates were likely influenced by changes in fishery management. Management changes during this time period included the closure of the directed black rockfish hook-and-line fishery in 1996, the closure of trawling inside 3 miles in 2000, and

the federal closure for non-trawl from shore to 100 fms beginning in 2003. These closures remain in place today (Table 38 and Figure 13).

The number of tags recovered is also quite variable among the number of years at large (Table 39). Recovery rates (number of tags recovered/number of releases) for a most tag groups (year) decreased substantially on an annual basis following the year of release, while tag recovery rates from 1998 and 1999 release group increased during the second recovery year (Table 40 and Figure 14). This is a consequence of many possible reasons, such as tag loss, fishing and natural mortality, and immigration. However, comparison of cumulative recoveries across time indicates that much of the difference in the overall recovery rates between release groups is owing to the variable proportion of tags being recovered during the year of release (Table 41 and Figure 15). The variability of first year recovery rate may be due to a number of reasons including geographical proximity of releases to high recreational fishing effort areas. However, it also appears that recovery rates of certain release groups remained high through time, even without the influence of first year recovery (Figure 16).

As shown in earlier tagging studies, the number of recoveries by tag release area and tag recovery area declined as distance increased from area of release (Table 42 and 43). However, high proportion of recoveries from areas close to release sites may indicate a significant amount of movement between adjacent reefs (Table 44). This is not surprising since areas are divided into relatively small, 2 nautical mile (3.7 km) blocks of latitude.

3. Other related experiments and studies and results

3.1 Immediate tag loss

There are two sources of information that provided data to estimate immediate tag loss defined here as tag loss occurring immediately after release. These included; 1) tag loss data collected during 30-day holding experiments and, 2) tag loss data collected from tagged fish that died shortly after release and were subsequently recovered (found floating on surface). These data provide insight into tag loss that transpired immediately following tagging for several different tag types.

Results

Tag loss was not observed for any individual or group of tagged fish that were held for 30 days of observation after tagging. However, immediate tag loss was observed in the field from fish double tagged with CWT that died and then were recovered at-sea during tagging. A simple calculation of the probability of tag loss (number of fish that lost one tag/total number recovered) indicates an estimated instantaneous tag loss rate of for CWT of 0.0452 (Table 45). We believe that the failure to detect observable tag loss in the holding experiments was likely due to the controlled conditions under which tagging took place. Here, tagging was simply not influenced by environmental conditions found at sea.

3.2 Long-term tag loss

Double tagging experiments for each tag type were included in tagging protocols throughout the study to provide information on tag loss. Spaghetti tag shedding rate was estimated from information on the number of fish initially double tagged and then later recovered with a single tag. Similarly, information on the number of fish initially double tagged with CWT tags, or a PIT tags and CWT, and then later recovered with a single tag was used to estimate tag shedding rates for PIT tags and CWTs.

Tag shedding rates for spaghetti tags were first estimated using the Chapman-Fink-Bennett (CFB) Model by Lai and Culver (1992) following Chapman et al. (1965). The model choice was made since there is no prior knowledge on the assumptions of immediate tag loss and the model assumes a constant rate of tag lost and mortality. Here we also use the CFB model and update spaghetti tag loss rates estimated by Lai and Culver, 1991 and provide new tag loss rates for both CWTs and PIT tags. Data were grouped by time of capture, across all years for each tag type.

Results

Tag loss data were grouped by time-at-large in annual increments across all years for each of the three key tag types: spaghetti tags, CWTs and PIT tags. Between 1981 and 1993 nearly 150 fish double-tagged with spaghetti tags were recovered, some tagged fish were at large for 10 years (Table 46). The estimated CFB instantaneous tag loss rate for Floy spaghetti tags was substantial with less than half of the fish retaining a tag by the fourth year at liberty (Table 47 and Figure 17). Biotic growth (Figure 18) on tags was likely a contributing factor to tag shedding and poorly applied tags would be more likely to fall out in the first year, artificially inflating early loss numbers.

Tag shedding rates of fish tagged with CWT's and PIT tags were considerably lower than fish tagged with spaghetti tags. Over 3,000 fish double tagged with CWTs were recovered, with some at liberty for nine years (Table 48). There was no observed difference in CWT tag loss between right and left sides of the fish (Table 49). The CFB estimate of instantaneous tag loss rate was very low (0.0035). Nearly 850 fish double tagged with a PIT tag and a CWT were recovered (Table 51). Some were at liberty for over 4 years. The CFB estimate of instantaneous tag loss for PIT from this group of fish was very small (0.007). However, data were quite variable (Table 52) and the model did not fit well (Figure 20).

3.3 Non-reporting

One of the critical assumptions for estimating population abundance or developing population abundance trends using tag recovery data is that all tags recovered by the fisheries are fully reported. Although a $10.00 -$50.00 reward was used as incentive for fishers to return tags, it became apparent to Department staff that not all of the tags recovered in the fishery were returned. Unsubstantiated reports from field samplers suggested that a non-negligible portion of charter and private fishers refused to return tags because they thought that returning tags would lead to reduced bag limits. Since we lacked the information necessary to estimate the fraction of recovered tags to unreported

tags, the 1999 black rockfish population dynamics model outcome was bracketed to incorporate this uncertainty.

We have no direct observations of non-reporting, and thus are unable to provide estimates. The influence of this parameter was explored within the black rockfish assessment conducted in 1999 (Wallace et al., 1999) by using three hypothetical tag-reporting rates: 75%, 50% and 25% (Table 53 and Figure 21). The reporting rate was held constant over time. The influence of reporting rate on recent (1999) biomass is small; however, it can triple the historical biomass estimates. This will affect stock status determination and thus different management actions may need to be considered.

3.4 Tag detection experiments

A series of experiments were conducted to test for the reliability of CWT and PIT tag detectors. Beginning in 1998, all fish sampled at dockside were scanned for tags by a CWT detector, R8000 (Northwest Marine Technologies). In 2004, we began tagging fish with PIT tags and port sampling methods were revised so that if a positive detection was made by the R-8000, a portable PIT tag reader (Allflex) was then used to detect the possible presence of a PIT tag. However, the R8000 was not designed to detect PIT tags since PIT tags are non-ferrous. The low observed tag recovery rates of single PIT tagged fish in 2004 supported this (0.01%). To ensure detection with the R8000, any fish tagged with a PIT were also tagged with a CWT. However, in 2005-2008 tag recovery rates for the 2004 single PIT tagged group was similar to tag recovery rates of other tag groups that had at least one CWT (Tables 54 - 58, and Figure 22-23). This lead to several follow up studies to provide insight into the reliability of the R-8000 to detect single PIT tagged fish and fish tagged with CWT and PIT tag. Study methods and results are described below.

In the first tag detection experiment, we hypothesized that energizing of the PIT tag may cause interference in the R-8000 detection process via the PIT tag radio wave transmission accounting for a positive detection. First, we measured the detection probability of R-8000 using two tag groups: 10 single CWT tagged fish and 90 untagged fish as a control. Next, an R-8000 and Destron 2001F-ISO (PIT tag data logger) were used to test the detection characteristics of both CWT and PIT tags and to test between-detector interference. A PIT tag embedded inside a plastic salmon (3.5” FL) supplied by PTAGIS Columbia Basin Systems Information was used to test interference by varying the speed that a PIT tag was sent through the R-8000. A one-half inch diameter wooden dowel approximately one meter long was attached to the plastic salmon by electrical tape to allow the tag’s speed through the detection apparatus to be controlled. Next, a PIT antenna was placed touching the exit of the CWT detector and then distance between the two detectors was increased to test if between-detector interference was affecting tag detection probability.

In a second study, we used three tag groups: 10 single CWT tagged fish, 18 coated PIT tagged fish and 72 untagged fish as a control, to test the detection probability of two tag types using three detectors (R-8000, Allflex and Destron PIT tag readers). The coating

on the “coated” PIT tags manufactured by Allflex is designed to allow for improved retention rates.

In a third study, we tested the detection probability using the same three detectors and four tag groups: 10 single CWT tagged fish, 18 coated PIT tagged fish, 22 single CWT and coated PIT tagged fish, and a 50 untagged fish control. In the final study, using the same three detectors, we tested five tag groups: 18 coated PIT tagged fish, 22 single CWT and coated PIT tagged fish, 16 red PIT tagged fish, 11 single CWT and red PIT tagged fish and 23 untagged fish as a control. The “red” PIT tags are normal un-coated PIT tags manufactured by Destron. During testing, fish were passed through the R-8000 at speeds that simulated those used during our mark sample recovery. Tagged fish were held and rotated for 4 seconds in front of the PIT tag detectors to provide time for the tag to be energized and detected.

Results

Results from the tag detection experiments indicate dissimilar detection characteristics between PIT and CWT tags and among detection apparatuses. The R-8000 does best (90%) detecting PIT tags at very fast speeds, while the Destron reliably (100%) pick up PIT tags at slow speeds (Table 59). To further complicate matters, the R-8000 appeared to cause interference with the PIT data logger paddle antenna. The interference was found to be minimized at paddle antenna distances of >6 inches from the exit of the R-8000 (Table 60). Negligible increases in antenna current occurred as distance from R-8000 increased from 6inches away. The R-8000 proved to be very reliable for detecting CWT through all trials (Table 61), independent of the rate tagged fish were passed through the detector. Trials using a combination of the Destron PIT tag readers and the R-8000 indicate that neither detector was reliable for detecting “coated” PIT tags (Table 62).

Results from multiple tag detection experiments using different combinations of tag types and tag detectors yielded important results (Tables 63-65). First, the Destron reliably detected red (uncoated) PIT tagged fish with or without an additional CWT. Second, fish tagged with the coated PIT tag only were almost never detected by the R-8000 (Tables 59-60). Based on these results, to maximize tag recovery rates, all tag release groups following 2004 always included at a combination of uncoated PIT and CWT or fish were double tagged with two CWT.

It is clear that the overall recovery rates for fish tagged with single PIT tags is lower (up to ~2.5%), but inconsistent across years compared to fish tagged with CWT (Table 66 and Figure 22). This result may largely be due to using the R-8000 as the primary detector since the detection rate for PIT tags is less than 100% and unknown. We considered scanning all fish with both the R-8000 and PIT tag detector, but discarded this idea; due to the large volume of fish sampled during a single day and the increased time involved in scanning every fish using both detectors, it would be impossible to maintain a large sample size. Because of this, we chose to use the R-8000 as the primary detector and tag all fish with at least one CWT following 2004. Further, we continued to scan fish secondarily only if a tag was first detected by the R-8000. We note that information used to draw conclusions on detector reliability could not be found and are therefore based on the data analyses and conclusions drawn by the previous tagging supervisor. It is

apparent that testing detector reliability and interference of multiple detectors is a very important aspect to any program reliant upon detectors to recover tagged fish.

3.5 Immediate tagging mortality

There are two possible sources of data to evaluate immediate mortality due to tagging, holding experiments, and data collected from fish that were recovered immediately following tagging due to death (found floating on the surface). A total of 103 fish, 53 tagged and 51 not tagged (control), were held for nearly a month in the Westport aquarium in 2003. Unfortunately, the experiment ended prematurely because the aquarium failed to maintain adequate oxygen levels and all of the fish died.
Several short-term mortality experiments were carried out throughout the study period. Each experiment included a control group of untagged fish and a group of fish tagged with various tag types (spaghetti, CWT and/or PIT tags) that were used throughout the rockfish tagging project. Tagged and untagged fish were held for 30 days in either a net pen in the Westport boat basin or in the Westport aquarium. Both tagged and released fish and those used in this experiment were selected because they did not show any serious external signs of barotrauma.

Beginning in 2005, barotrauma and hook injuries for tagged fish were documented. These data were collected to test the assumptions that fishes with "minor" injuries were suitably fit and would recover without apparent side effects similar to tagged fish without any apparent injury. Along with depth of capture, injuries were classified as "Yes" or "No" for seven barotrauma and/or injury categories including: 1) "Hook Blood" if bleeding in the head area, 2) "Gut Tight" if the membrane in the gut was tight from expanded air, 3) "Membrane Bulge" if the gill membrane was extended or tight, 4) "Eye Bulge" if the eye was bulging due to air expansion, 5) "Eye Air" if there were air bubbles within the eye membrane, 6) "Jab Blood" if there were external body injuries and 7) "Hit Deck" if the fish was dropped on the deck. Fishes that presented significant injury such as blood loss from the gills or severe barotraumas such as a fully extended bladder were not tagged. The assumption that fishes with "minor" injuries would recover without side effects was tested through comparison of recovery rates for fishes with and without any apparent injury. We also analyzed barotraumas data collected for fish that were tagged and died immediately following release. These fish were recovered to help provide insight into which injuries or combination of injuries may affect mortality.

Results

Comparison of the cumulative proportion of fish that died in the control group with the tagged group of fish during the 2003 study indicates that mortality rates were very similar between groups throughout the experiment (Figure 24). In 2005, 50 tagged and 50 not tagged (control) were held in a net pen in the Westport boat basin. The water quality was poor and fish soon developed skin lesions and fungus growth. By the end of a month nearly all fish died, but cumulative mortality between the control and tag group was largely similar. Both of these short term studies suggest that tagging does not induce appreciable additional short-term mortality on fish.

There were a total of eight different types of injuries recorded by field staff and this resulted in a numerous possible combinations recorded for any single fish (Table 67). Of the approximately 14,000 fish tagged and released, 52% experienced no injuries, 43% experienced one minor injury and approximately 5% suffered more than two injuries (Table 68). Data collected from fish that were tagged, released and then subsequently died indicate that short term mortality increased as the number of injuries increased (Table 69). It was difficult to discern if any single injury was more responsible for death than another given the large variety and combination of injuries observed. Further, there appeared to be no relationship between the number of tag mortalities and tag type (Table 70). As expected, the deeper the tagging site the more likely a fish would suffer barotraumas and mortality compared with shallower sites (Table 71).

In our first year of recording injury observations, a total of 1,507 fish had no injuries and 270 had at least 1 injury. Seventeen were observed to have injuries in at least three injury categories and no fish were observed to have injuries in more than three categories (Table 72). A much greater percent of the tagged and released fish were observed for injuries in following years and observations of fish with cumulative injuries declined sharply with the greatest percent only having a single injury. Recoveries of fish with and without multiple injuries were made in subsequent years (Table 73). The recovery rate for tagged fish with increasing number of injuries was observed to decline for the 2005 and 2007 release groups, but an opposite trend was observed for the 2006 release group (Table 74). Based on these observations, it is difficult to unequivocally determine a direct relationship between the number of injuries or type of injury and the rate of recovery. It is apparent that the number of injuries is directly related to the probability of the fish dying immediately following tagging and this is clearly illustrated in Table 69. However, the number of fish that sustained multiple injuries is small relative to those with none, or a single injury, and would likely have little observable effect on recovery rates.

3.6 Growth validation

The need to substantiate an accurate ageing technique is essential in constructing growth models, which form the base for many conventional stock assessment models. Validation of the ageing technique is required for each species to ensure accurate age estimation (Beamish and McFarlane 1983, Six and Horton 1977). Weber and Ridgway (1962) found that OTC injection creates a discrete mark on calcified structures that is visible under ultraviolet lighting. This experiment is based on a mark and recapture program of OTC-injected black rockfish to validate annuli formation using the break-and-burn ageing technique (Yoklavitch and Boehlert, 1987). Recovery rates for OTC-injected and non-injected fish were evaluated to gain insight into possible mortality induced from injection of OTC.

Between 1981 and 1983 a total of 6,252 black rockfish were tagged and released aboard Department vessels and of these, 1,575 were also injected with OTC (Table 75). During this same time period 2,483 were tagged and released aboard sport charter vessels of which 299 were also injected with OTC (Table 76).

Results

A total of 11 and 18 OTC-injected fish were recovered from tag releases in 1981 and 1982 respectively. No OTC-injected fish were recovered from tag releases in 1983. Otoliths from 13 of the 29 recovered OTC-injected fish were lost and could not be processed. The quality of the OTC mark was very good on all of the otoliths examined and in several cases both the OTC mark and growth rings could be seen when photographed under ultraviolet light. Recovered fish whose otoliths were processed were at liberty from 64 to 2,614 days (7 years) and ranged in age from 6 to 19. The number of features, designated as annuli with the ageing method, corresponded exactly to the number of annuli expected from the time at liberty (Table 77).

Analysis of deposition patterns prior and subsequent to the OTC mark suggests that narrow translucent bands (annuli) within the otoliths develop during fall with wide opaque bands (faster otolith growth) being laid down early in the year. The first annulus subsequent to the OTC mark was very close for fish injected and released in late summer (August). Otoliths from fish released in May exhibited a limited amount of growth before first annuli development subsequent to the OTC mark. Otoliths of fish recovered in August and September possessed wide opaque zones on the margin that were fully developed without bordering annuli. Final annuli of fish recovered during spring (late May) were followed by wide growth zones that were nearly complete in some cases.

3.7. Movement

Tag release and recovery data are commonly used to evaluate movement for marine fishes. These studies are important for defining the spatial distribution of a population and examining the relative spatial impacts of fishing. Important considerations include how far they move, whether they discriminate among habitats and whether movement is related to life history needs such as spawning locales.

It is clear from our tagging data that the majority (75%) of black rockfish were recovered near their release site, but that black rockfish can and do display significant movement (Table 78). Approximately 85% of the recoveries are recovered within 20 k of their release location, but distance from release site is shown to generally increase with time at liberty with some observable drop for fish recovered after 4 and 6 years at large and then increasing again (Tables 79 and 80, Figure 25). This pattern is relatively consistent among release groups demonstrating a slow dispersion of fish from their original capture site over a number of years (Figure 26).

Fish have been tagged and released across five of the six geographic areas continuously since 1985. Over 52,000 fish were tagged with the following distribution by area: Cape Falcon (15%), Grays Harbor (24%), Cape Elizabeth (15%), La Push (25%) and Neah Bay (20%) (Table 81). Due to the lack of rocky habitat, no tagging effort was expended in the Columbia River area. Overall recovery rates varied considerably among geographic areas (2%-8%) with the highest recovery rates from Grays Harbor releases (Table 82). However, recovery rates are largely driven by the spatial distribution of recreational and commercial harvests and the Grays Harbor is one of the most heavily fished areas targeting black rockfish.

Data suggest that there is little movement of black rockfish from the study area to areas south of Cape Falcon compared to the Cape Falcon to Cape Flattery area. Only 13 out of nearly 2,000 recoveries were made south of Cape Falcon though recreational and commercial fisheries were ongoing throughout the study period (Table 83) and Oregon port samplers were aware of and looking for any tag recoveries in their recreational fisheries. However, observed movements of tagged fish were substantial within the Cape Falcon to areas inside San Jaun De Fuca straits near Neah Bay. Cape Falcon releases by release year and by geographic area show that a sizeable proportion of fish were recovered to the north. Overall, 26.8% and 6.7% were recovered in the Columbia River and Grays Harbor vicinity, respectively (Table 84 and Figure 27). Relatively few Grays Harbor area releases were recovered from areas to the north (Table 85 and Figure 28), whereas in 1981 and 1982 recoveries at Columbia River accounted for 24% and 41%, respectively, of the total recoveries of Grays Harbor releases, with substantially fewer thereafter.

The fate of Cape Elizabeth releases by release year and percent of total recoveries by geographic area show that the greatest proportion of tags (61%) were recovered to the south in Grays harbor (Table 86 and Figure 29). Nearly 30% of the La Push area releases were recovered in the Grays Harbor area and 25% were recovered to the north in the Neah Bay area (Table 87 and Figure 30). The majority (78%) of Neah Bay releases was recovered within the Neah Bay area, but approximately 14% were recovered near Grays Harbor (Table 88 and Figure 31). Although the majority of fish were recovered relatively near their release site, some fish were found to move substantial distances (Figure 32).

It is clear that the number and proportion of recoveries by area of release is a function of the type of fishery (target or not) and magnitude of the fishery operating in that area. The relative magnitude of the fishery is largely controlled by management regulations that have changed considerably in both the commercial (Figure 33) and sport fisheries (Figure 34). As a result of more conservative rockfish regulations, especially for the commercial fisheries, black rockfish harvest shifted entirely from commercial fisheries to the sport fishery. By 1997, nearly all of the black rockfish harvest was taken by the sport fishery, and most of that by the Grays Harbor sport charter boat industry (Figure 35 and 36). Nearly all of the recoveries made in the Columbia River area were by the trawl fishery and as this fishery declined so did the recovery of tags from this area. Because of the potential biases resulting from effort changes among areas it will be necessary to address these issues in any movement model. Model development and assumptions will be addressed outside of this document.

4. Incorporation of tagging data into Stock Assessment

Tagging results have been incorporated into the black rockfish population dynamics model using various methods. The first assessment, conducted in 1994 (Wallace and Tagart, 1994), incorporated the tagging CPUE time series as a fishery independent survey. These data informed the model on the relative population trend, which was declining during that time period.

Tagging data were directly integrated into the 1999 black rockfish population dynamics model (Wallace et al, 1999) as a separate likelihood function. Tagging data essentially

provided information to "tune" population dynamics and were incorporated directly into the assessment. Detail on the approach used can be found in the assessment.

In the 2007 black rockfish assessment (Wallace et. al., 2007), Petersen's method (Chapman, 1951) was used to estimate the population size from capture and recapture data (Table 89. Population estimates and tagging CPUE were incorporated directly as tuning indices.

Descriptions on how tagging information influenced assessment results can be found within the assessments, so only general assessment results are describe below. The 1994 assessment indicated that the stock had suffered significant decline due to poor recruitment and over fishing. The 1999 black rockfish stock assessment indicated the same population decline. However, because there were no data available on non-reporting of tags, model sensitivity on this parameter was required to bracket the assessment results (Figure 37). The 2007 assessment estimated the same declining stock trends through the 1990s as was seen in the previous two assessments. However, significant recruitment in the late 1990s allowed population abundance to increase to healthy levels, well above management thresholds increasing to a population magnitude last seen in the early 1980s. Model fit to the population indices derived from tagging data can be found in Figures 38 and 39.

5. Discussion

Although methods to incorporate tagging data have varied between assessments, tagging information has provided key and essential data to determine population dynamics for the Coastal Washington black rockfish stock. Continuation of a data collection program that measures biomass or population trends such as the current tagging program is a requirement for future stock assessment of this species.

There have been a number of key findings from earlier tagging studies that have been used to modify and improve the tagging program including: 1) internal tags (CWT or PIT) that are not visible have a much lower tag-shedding rate than external tags; 2) the issue of non-reporting is eliminated by using catch samples; 3) all fish are tagged with at least one CWT that can be consistently detected at fast sampling rates; 4) and tags are released proportionally to the known distribution of black rockfish off the central coast.

Although the tagging program has been much improved in recent years, suggestions for further improvement are outlined in the appendix and noted by the STAR Panel during the 2007 assessment review (Appendix A). At the end of a series of requests from the STAR Panel a base case model was produced, but a number of deficiencies in the current tagging program that could affect model outcome were highlighted. Effective q (catchability- here it represents the proportion of total black rockfish habitat covered by the study) for the tagging index was estimated at 0.83 and given that tags are distributed on less than half of the available habitat off coastal Washington this was perhaps twice what it should be. However, this is somewhat complicated since the SS2 value of q is a function of selectivity which is strongly dome shaped for the associated fishery. Without an objective evaluation of an informed prior on q it is difficult to compare a prior conception of q based on tagging and the one estimated by SS2. It was agreed that this

was the best scientific information available at the moment, but there are reservations about the q for the survey and that this dimension was not explored since little information is available on rocky habitat distribution in near shore areas.

It was also noted during the STAR Panel discussions that the distribution of the recreational fishing fleet changes through time due to economic factors. It is questionable whether the assumption of mixing between tag and release holds depending on how far the tagged fish move, and the extent of overlap between tagging and release fishing effort. It is not possible to determine from returns where the fish were recovered. The Panel noted that it would be worthwhile to carry out a study to determine whether there has been any trend in the spatial fishing pattern that may cause a bias in this index. This could largely be accomplished by requiring a charter logbook program, but until this happens it remains difficult to measure changes in the spatial distribution of the recreational fleet.

Expansion of the tagging program coast-wide would not only greatly improve our ability to estimate tagging *q,* but also allow thorough monitoring of the entire "assumed" stock area found between Cape Falcon, Oregon and Cape Flattery, Washington. The assumption that this is an independent stock is supported by the movement information that shows there is little movement of black rockfish areas south of Cape Falcon. Although the majority of fish are recovered relatively near their release site, many fish are found to move substantial distances within the Cape Falcon to Neah Bay study area. Furthermore, it was found that recovery distance from release site increased with time suggesting important mixing of the stock within the study area between lightly exploited areas in the north to more highly exploited areas to the south.

Observed movement within the study area and proportion of recoveries by area of release is a function of the type of fishery and magnitude of the fishery operating in that area. The relative magnitude of the fishery is largely controlled by management regulations that have changed considerably in both the commercial and sport fisheries. More conservative rockfish regulations especially for the commercial fisheries have resulted in shifting black rockfish harvest away from the commercial fisheries to the sport fishery. Nearly all of the black rockfish harvested is now harvested by the sport fishery, and most of that harvest is by the Grays Harbor sport charter boat industry. Nearly all of the recoveries made in the Columbia River area were by the trawl fishery and as this fishery declined so did the recovery of tags from this area. Because of the potential biases resulting from effort changes among areas it will be necessary to address these issues in any movement model. Movement should be addressed in future stock assessment models to ensure full integration of the population dynamics for this stock. This will be evaluated by estimating movement parameters in future population dynamics models.

6. Literature Cited

Anganuzzi, A., Hilborn,R., and J.R. Skalski 1994 Estimation of size selectivity and movement rates from mark recovery data. Ca. J. Fish. Aquat. Sci. 51, 734-742

Chapman, D. G., Fink, B.D., and E.B. Bennett 1965. A method for estimating the rate of shedding of tags from yellowfin tuna. IATTC Bull. 10:332-352.

Boettner, J.F. 1992. Hydroacoustic stock assessment studies of the coastal black rockfish from 1989 to 1991 in Washington State. Wash.Dept. Fish Tech. Rept. No 26

Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at Pacific Biological Station. Ca. Spc. Pub. of Fish. and Aquat. Sci. 60.

Beamish, R. J., and D. E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (*Anoplopoma fimbria*). Ca. J. Fish. Aquat. Sci. 39:277-287.

Beamish, R. J., and G. A. McFarlane. 1983. Forgotten requirements for age validation in fisheries biology. Transactions of the American Fisheries Society 112(6):735-743.

Kobayashi, S., Yuki,R., Furui, T., and T. Kosugiyama. 1964. Tetracycline labelling patterns on scale, centrum and otolith in young goldfish. Bull. of Japan. Soc. of Sci. Fish. 30:6-13.

Lai, H. and B. N. Culver. 1991. Estimation of tag loss rate of black rockfish (*Sebastes melanops*) off the Washington coast with a review of double tagging model. Wash. State Dept. Fish. no: 113

Leaman, B. M., and D. A. Nagtegaal. 1987. Age validation and revised natural mortality rate for yellowtail rockfish. Transactions of the American Fisheries Society 116:171-175.

Love, M.S., Yoklavitch, M., and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. Univer. Cal. Press. 441 p.

Simkiss, K. 1974. Calcium metabolism of fish in relation to ageing. Pages 1-12 in T. B. Bagenal, ed. Ageing of Fish, Unwin Brothers Limited, Surrey, England

Six, L. D., and H. F. Horton. 1977. Analysis of age determination methods for yellowtail rockfish, canary rockfish and black rockfish off Oregon U.S. National Marine Fisheries Service Fisheries Bulletin 75:405-414.

TCW Economics, 2008. Economic Analysis of the Non-Treaty Commercial and Recreational Fisheries in Washington State. Prepared for the Washington Department of Fish and Wildlife, 49 pages.

Wallace, F.R. and J.V. Tagart, 1994. Status of the coastal black rockfish stocks in Washing and northern Oregon in 1994. *In* Pacific Fisheries Management Council. 1994. Appendix F: Status of the Pacific Coast Groundfish Fishery Through 1994 and Recommended Acceptable Biological Catches for 1995: Stock Assessment and Fishery Evaluation. Pacific Fisheries Management Council, Portland OR.

Wallace, F.R., Hoffmann, A., and J.V. Tagart, 2000. Status of the Black Rockfish Resource in 1999. In Pacific Fishery Management Council. 1999. Appendix: Status of the Pacific Coast Groundfish Fishery Through 1999 and Recommended Biological Catches for 2000: Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, Portland, OR.

Wallace, F.R., Cheng Y. W., and T. Tsou, 2007. Status of the black rockfish resource north of Cape Falcon, Oregon to the U.S.-Canadian border in 2006. Stock Assessment and Fishery Evaluation Report. Pacific Fishery Management Council, Portland, OR.

Weber, D. D., and G. J. Ridgway. 1962. The deposition of tetracycline drugs in bones and scales of fish and its possible use for marking. Progressive Fish Culturist 24:150-155.

Yoklavich, M. O., and G. W. Boehlert. 1987. Dailey growth increments in otoliths of juvenile black rockfish, Sebastes melanops: An evaluation of autoradiography as a new method of validation. Fish. Bull. 85(4): 826-832.

Zar, J. H. 1984. Biostatistical Analysis. Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 656 pages.

7. Tables

Table 1. Latitudinal strata used for distribution of tagging effort between 1986 and 1990.

	Latitude (Decimal Degrees)	
Tagging Area	Southern Boundary	Northern Boundary
1a	45.78333	45.94444
1b	45.94445	46.10556
1c	46.10557	46.26667
3a	46.83333	47.00000
3b	47.00001	47.16668
3c	47.16669	47.33335
5a	47.33333	47.44444
5b	47.44445	47.55556
5c	47.55557	47.66667
6a	47.66667	47.78889
6b	47.78890	47.91112
6c	47.91113	48.03334
7a	48.03333	48.14722
7b	48.14723	48.26112
7c	48.26113	48.37501
8	48.37502	48.49201

Table 2. Number of pinnacles in 2° latitudinal strata and distribution of total tagging effort (700 angler hours) by habitat and area.

		Latitude (Decimal Degrees)		Percent of	Effort [1/]
Area	No. of Pinnacles	Southern Boundary	Northern Boundary	Total Effort	(Rod Hours)
1	3	46.90000	46.93333	0.5%	3.8
2	0	46.933333	47.000000	0.0%	0.0
3	24	47.000000	47.033333	4.4%	30.7
4	25	47.033333	47.066667	4.6%	31.9
5	4	47.066667	47.100000	0.7%	5.1
6	23	47.100000	47.133333	4.2%	29.4
7	61	47.133333	47.166667	11.1%	77.9
8	32	47.166667	47.200000	5.8%	40.9
9	90	47.200000	47.233333	16.4%	115.0
10	53	47.233333	47.266667	9.7%	67.7
11	22	47.266667	47.300000	4.0%	28.1
12	24	47.300000	47.333333	4.4%	30.7
13	73	47.333333	47.366667	13.3%	93.2
14	60	47.366667	47.400000	10.9%	76.6
15	15	47.400000	47.433333	2.7%	19.2
16	14	47.433333	47.466667	2.6%	17.9
17	25	47.466667	47.500000	4.6%	31.9
Total	548			100%	700

1/ Assumes total effort (rod hours) will be 700 hours

Table 3. Number of black rockfish tagged and released by release year and tag type (1SPG = one spaghetti tag., 1SPGOTC =one spaghetti tag plus OTC, 2SPG= two spaghetti tag and 2SPGOTC= two spaghetti tags and OTC) between 1981 and 1990.

Year	1SPG	1SPGOTC	2SPG	2SPGOTC	Total
1981	3,379	988	292	80	4,739
1982	1,697	607	170	67	2,541
1983	1,787	122	114	10	2,033
1984	643		31		674
1985	4,727		113		4,840
1986	5,494		365		5,859
1987	5,243		59		5,302
1988	7,898				7,898
1989	8,346		862		9,208
1990	7,979		969		8,948
Total	47,193	1,717	2,975	157	52,042

Table 4. Total number of tag releases by Punch Card Area (PCA) between 1981 and 1990.

Year	PCA1	PCA2	PCA3	PCA4	Total
1981		4,739			4,739
1982		2,171		370	2,541
1983	1,199	109		725	2,033
1984				674	674
1985	1,283	2,409		1,148	4,840
1986	784	2,273	1,908	894	5,859
1987	1,075	1,357	1,939	931	5,302
1988	1,085	2,726	2,739	1,348	7,898
1989	1,414	2,440	2,911	2,443	9,208
1990	1,038	2,444	3,602	1,864	8,948
Total	7,878	20,668	13,099	10,397	52,042

Table 5. Total number of releases and percent of total releases by tagging area strata 1981-1990.

Total number of releases by tagging area strata.

Year	1B	1C	3A	3B	3C	5B	5C	6A	6B	6C	7A	7B	7C	8	Total
1981			554	3254	244		687								4739
1982				445	5	1721					55	315			2541
1983	1094	105	109								248	477			2033
1984											262			412	674
1985	755	528	200	1501	515		193				384			764	4840
1986	542	242	335	540	210	785	403	1182	459	267	219	602	73		5859
1987	742	333	341	586	109	321		472	1251	216	173	758			5302
1988	470	615	985	298	81	387	975	382	936	1421	175	685	488		7898
1989	1139	275	973	209	97	477	684	996	853	1062	387	1132	924		9208
1990	419	619	619	316	179	512	818	1097	1720	785	273	811	780		8948

Percent of total releases

1981			12%	69%	5%		14%								100%
1982				18%	0.2%	68%					2%	12%			100%
1983	54%	5%	5%								12%	23%			100%
1984											39%			61%	100%
1985	16%	11%	4%	31%	11%		4%				8%			16%	100%
1986	9%	4%	6%	9%	4%	13%	7%	20%	8%	5%	4%	10%	1%		100%
1987	14%	6%	6%	11%	2%	6%		9%	24%	4%	3%	14%			100%
1988	6%	8%	12%	4%	1%	5%	12%	5%	12%	18%	2%	9%	6%		100%
1989	12%	3%	11%	2%	1%	5%	7%	11%	9%	12%	4%	12%	10%		100%
1990	5%	7%	7%	4%	2%	6%	9%	12%	19%	9%	3%	9%	9%		100%

Table 6. Total effort (rod hours) recorded by tagging area and percent of total effort recorded in each area. Time spent fishing data was incomplete for early years.

Number of rod hours spent fishing in each area[1/]

Year	1a	1b	3a	3b	3c	5a	5b	6a	6b	6c	7a	7b	7c	8	Total
1981				264	131	120									516
1982							237					90		57	385
1983	324											161	34	42	561
1984													66	93	158
1985															0
1986	175	122	35	103	192	283		76	112	170		198	146		1611
1987	230		31	216	337	31	73	84	135	116		203	128		1583
1988	180			43	169	143	47	125	60	23	45	243	161		1238
1989	426	7	51	38	184	95	56	128	161	227	99	258	193		1923
1990	355	29	4	242	214	201	31	184	112	229	96	257	132		2085

Percent of total releases

1981				51%	25%	23%									100%
1982							62%					23%		15%	100%
1983	58%											29%	6%	8%	100%
1984													41%	59%	100%
1985															
1986	11%	8%	2%	6%	12%	18%		5%	7%	11%		12%	9%		100%
1987	15%		2%	14%	21%	2%	5%	5%	9%	7%		13%	8%		100%
1988	15%			3%	14%	12%	4%	10%	5%	2%	4%	20%	13%		100%
1989	22%	0%	3%	2%	10%	5%	3%	7%	8%	12%	5%	13%	10%		100%
1990	17%	1%	0%	12%	10%	10%	1%	9%	5%	11%	5%	12%	6%		100%

1/ Note: Effort statistics incomplete in most years

Table 7. Number of black rockfish tagged and released by release year and tag type (1CWT= one coded wire tag, 1CWT1PIT=one coded wire tag and one PIT tag, 1 PIT=one pit tag, 2CWT = two coded wire tags) between 1998 and 2007.

Release Year	1CWT	CWT1PI	1PIT	2CWT	Total
1998	172			2451	2623
1999				3476	3476
2000				2786	2786
2001				3208	3208
2002				4088	4088
2003	6			6687	6693
2004	1	863	1049	4190	6103
2005		3721	33	3	3757
2006		6031			6031
2007				5376	5376
Totals	179	10615	1082	32265	44141

Table 8. Distribution of angler hours by tagging area strata (1998-2009).

	Distribution of Angler Hours																
Year	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1998	1.4%	0.4%	12.0%			13.5%	21.7%	3.1%			1.8%	17.0%	14.8%	3.7%	0.2%	10.4%	100.0%
1999	0.1%		1.3%		3.5%	8.4%	32.4%					27.6%	20.1%	1.5%		5.1%	100.0%
2000						8.2%	38.7%					23.7%	29.4%				100.0%
2001			0.6%		3.7%	2.7%	20.0%	23.2%	14.2%	4.7%		14.2%	10.5%	6.2%			100.0%
2002	0.5%	4.1%	10.7%			17.0%	9.8%	12.2%	6.2%	2.0%	4.1%	18.7%	5.7%	2.8%	2.7%	3.6%	100.0%
2003	0.6%	5.0%	5.2%	0.8%	1.3%	7.1%	6.9%	16.1%	11.6%	4.4%	4.1%	13.9%	6.6%	7.8%	3.0%	5.8%	100.0%
2004	0.3%	4.7%	4.7%	0.8%	4.2%	12.3%	5.4%	14.6%	8.1%	3.7%	4.1%	17.1%	10.4%	2.4%	2.4%	4.6%	100.0%
2005	0.7%	3.9%	4.1%	1.5%	3.7%	3.7%	11.3%	18.8%	16.4%	2.0%	3.9%	11.8%	9.6%	2.4%	2.3%	4.0%	100.0%
2006	0.5%	4.2%	4.5%	0.7%	4.3%	7.9%	6.9%	16.1%	10.1%	6.9%	4.3%	13.0%	10.9%	2.7%	2.5%	4.5%	100.0%
2007	0.5%	4.4%	4.7%	0.5%	4.2%	11.2%	5.8%	17.0%	9.8%	3.7%	4.4%	12.9%	10.9%	2.7%	2.6%	4.7%	100.0%
Target	0.5%	4.4%	4.6%	0.7%	4.2%	11.1%	5.8%	16.4%	9.7%	4.0%	4.4%	13.3%	10.9%	2.7%	2.6%	4.6%	
Mean	0.5%	4.4%	4.9%	0.9%	3.6%	8.8%	9.4%	16.9%	10.9%	3.9%	4.1%	14.5%	9.2%	3.9%	2.6%	4.5%	

Table 9. Total number of tag releases by tagging area strata (1998 - 2007).

	Number of releases																
Year	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1998	4		161			199	502	44				421	631			661	2623
1999			8		51	167	1349					642	1122	10		127	3476
2000						240	799					931	816				2786
2001			16		71	69	594	759	485	125		574	98	417			3208
2002			499			910	362	569	374		79	878	340	42		35	4088
2003	14	35	20	141	183	21	556	746	926	42	262	388	1001	1452	906		6693
2004		198	201	24	165	428	403	615	592	128	310	926	1047	285	303	478	6103
2005	2	74	192	15	68	135	421	516	296	78	124	691	530	279	54	282	3757
2006	8	175	303	19		505	482	875	563	364	170	820	939	271	178	359	6031
2007	8	237	197		155	465	380	904	400	71	390	608	892	236	4	429	5376
Total	36	719	1597	199	693	3139	5848	5028	3636	808	1335	6879	7416	2992	1445	2371	44141

Table 10. Total time spent fishing (angler hours) in each tagging area strata (1998 - 2007).

Angler Hours

Year	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1998	14	4	113			127	204	29			17	159	139	35	2	98	940
1999	1		11		28	66	255					217	158	12		41	788
2000						83	390					238	296				1007
2001			4		24	17	128	149	91	30		91	67	40			641
2002	3	25	66			105	61	75	38	13	25	116	35	18	17	22	617
2003	5	44	46	8	11	63	61	143	103	39	36	123	58	69	27	51	886
2004	2	32	32	6	29	84	37	100	56	25	28	117	71	16	17	32	684
2005	4	20	21	8	19	19	58	97	85	11	20	61	50	13	12	21	519
2006	3	24	25	4	24	44	39	90	57	39	24	73	61	15	14	25	562
2007	2	21	22	3	20	52	27	79	46	17	21	60	51	12	12	22	465
Total	33	169	340	28	155	661	1260	763	474	173	171	1255	987	229	100	311	7109

Table 11. Catch per unit effort (number of releases/angler hours) by tagging strata and year.

Catch per unit effort (Angler Hours)

Year	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Mean
1998	0.3	0.0	1.4			1.6	2.5	1.5			0.0	2.6	4.5	0.0	0.0	6.7	1.8
1999	0.0		0.8		1.9	2.5	5.3					3.0	7.1	0.8		3.1	2.7
2000						2.9	2.0					3.9	2.8				2.9
2001			4.0		3.0	4.1	4.6	5.1	5.3	4.2		6.3	1.5	10.5			4.9
2002	0.0	0.0	7.6			8.7	6.0	7.6	9.8	0.0	3.2	7.6	9.7	2.4	0.0	1.6	4.6
2003	2.7	0.8	0.4	18.8	16.1	0.3	9.1	5.2	9.0	1.1	7.3	3.2	17.2	21.1	33.6	0.0	9.1
2004	0.0	6.2	6.3	4.1	5.7	5.1	10.9	6.1	10.7	5.1	11.0	7.9	14.7	17.3	18.1	15.1	9.0
2005	0.6	3.7	9.1	1.9	3.5	7.1	7.2	5.3	3.5	7.4	6.2	11.3	10.6	22.2	4.5	13.4	7.3
2006	2.9	7.4	12.0	5.0	0.0	11.4	12.4	9.7	9.9	9.4	7.0	11.2	15.3	18.1	12.9	14.2	9.9
2007	3.6	11.5	9.0	0.0	7.9	8.9	14.0	11.4	8.8	4.1	18.9	10.2	17.6	19.1	0.3	19.8	10.3
Mean	1.3	4.2	5.6	6.0	5.4	5.3	7.4	6.5	8.1	4.5	7.6	6.7	10.1	12.4	9.9	9.3	6.3

Table 12. Catch per unit effort (number of releases/angler hours) in tagging area strata visited nine out of ten years.

Catch per unit effort (Angler Hours) for areas with effort 9 out of 10 years

Year	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Mean
1998			1.4			1.6	2.5					2.6	4.5	0.0			2.1
1999			0.8			2.5	5.3					3.0	7.1	0.8			3.2
2000						2.9	2.0					3.9	2.8				2.9
2001			4.0			4.1	4.6					6.3	1.5	10.5			5.2
2002			7.6			8.7	6.0					7.6	9.7	2.4			7.0
2003			0.4			0.3	9.1					3.2	17.2	21.1			8.5
2004			6.3			5.1	10.9					7.9	14.7	17.3			10.4
2005			9.1			7.1	7.2					11.3	10.6	22.2			11.3
2006			12.0			11.4	12.4					11.2	15.3	18.1			13.4
2007			9.0			8.9	14.0					10.2	17.6	19.1			13.1
Mean			5.6			5.3	7.4					6.7	10.1	12.4			7.7

Table 13. Total number of black rockfish sampled by month and year between 1986 and 1992.

Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1986			18306	37459	56668	81939	25079		219,451
1987	402	8336	33110	53446	58325	77809	40218	65	271,711
1988	14	12068	30836	54769	62267	82196	37294	2211	281,655
1989		7258	35797	36853	48072	44670	41058	955	214,663
1990		8604	38287	43834	53547	50937	22392	1260	218,861
1991		9991	24842	35610	32992	46430	18890		168,755
1992		5262	30308	45788	40196	30614	15229	557	167,954
Total	416	51,519	211,486	307,759	352,067	414,595	200,160	5,048	1,543,050

Table 14. Total number of black rockfish sampled for tags by fishery between 1986 and 1992.

	Sport				Commercial					
Year	Bottomfish	Diving	Halibut	Salmon	Jig	Trawl	Troll	Set Net	Sal. Troll	Total
1986	205663		19	7098	6671					219,451
1987	239883	317	1019	6593	23899					271,711
1988	257685	648	2118	5933	15171			44	56	281,655
1989	186192	678	2742	10243	14481		206	43	78	214,663
1990	179712	603	3908	8124	26430		3		81	218,861
1991	153125	274	3990	6175	5184	4		2	1	168,755
1992	122051	423	3578	14857	27015		30			167,954
Total	1,344,311	2,943	17,374	59,023	118,851	4	239	89	216	1,543,050

Table 15. Total number of black rockfish sampled for tags by Punch Card Areas (PCA) between 1986 and 1992.

Year	PCA1	PCA2	PCA3	PCA4	Total
1986	5	199798	33	19615	219451
1987	4503	231533	5490	30185	271711
1988	10164	232897	3506	35088	281655
1989	5972	174197	1995	32499	214663
1990	5995	165980	13795	33091	218861
1991	3365	142702	3547	19141	168755
1992	4341	108142	20873	34598	167954
Total	34345	1255249	49239	204217	1543050

Table 16. Number of black rockfish sampled for tags from the sport fishery.

Year	PCA1	PCA2	PCA3	PCA4	Total
1986	5	199798	33	12944	212780
1987	4503	225070	1018	17221	247812
1988	10164	232897	2615	20708	266384
1989	5949	174144	969	18793	199855
1990	5995	165980	3106	17266	192347
1991	3365	142702	3478	14019	163564
1992	4341	108142	5959	22467	140909
Total	34322	1248733	17178	123418	1423651

Table 17. Estimated black rockfish catch from the sport fishery by PCA (Wallace et al., 2007).

Year	PCA1	PCA2	PCA3	PCA4	Sport
1981	11450	132986	314	15759	160,509
1982	8825	68383	1945	13537	92,690
1983	17435	136157	3715	25608	182,915
1984	8044	184921	1876	36714	231,555
1985	21603	189446	708	36411	248,168
1986	28651	258082	1304	31560	319,597
1987	20533	261799	1883	35481	319,696
1988	23832	272888	3576	36350	336,646
1989	24002	236201	3275	32729	296,207
1990	19955	254483	4551	35722	314,711
1991	12113	216244	5243	33936	267,536
1992	19190	183867	8493	62844	274,394
1993	22110	188814	6084	52656	269,664
1994	23769	240658	8196	28768	301,390
1995	14693	161422	8274	40502	224,892
1996	19491	162940	7119	53469	243,019
1997	19963	130885	3605	43874	198,327
Total	315659	3280177	70161	615920	4,281,916

Table 18. Number of black rockfish sampled for tags from the commercial fishery.

Year	PCA1	PCA2	PCA3	PCA4	Total
1986	0	0	0	6671	6671
1987	0	6463	4472	12964	23899
1988	0	0	891	14380	15271
1989	23	53	1026	13706	14808
1990	0	0	10689	15825	26514
1991	0	0	69	5122	5191
1992	0	0	14914	12131	27045
Total	23	6516	32061	80799	119399

Table 19. Estimated black rockfish catch from the commercial fishery (Wallace et al , 2007).

	Catch(mt)		Catch(#'s)		
Year	**Trawl**	**Non-trawl**	**Trawl**	**Non-trawl**	**Total (#'s)**
1981	185.1	128.9	211543	147314	358,857
1982	327.5	134.1	374286	153257	527,543
1983	218.9	145.8	250171	166629	416,800
1984	127.3	272	145486	310857	456,343
1985	158.6	103	181257	117714	298,971
1986	82	220.1	93714	251543	345,257
1987	129	129.3	147429	147771	295,200
1988	124.4	165.3	142171	188914	331,086
1989	43.3	119.4	49486	136457	185,943
1990	46.2	83.4	52800	95314	148,114
1991	71.4	132.3	81600	151200	232,800
1992	46.8	88.4	53486	101029	154,514
1993	1	106.3	1143	121486	122,629
1994	3.3	65.8	3771	75200	78,971
1995	0	8.6	0	9829	9,829
1996	9	15	10286	17143	27,429
1997	73.1	4.8	83543	5486	89,029
Total	1647	1923	1882171	2197143	4,079,314

1/ Wallace et al., based on the 2007 average weight 0.875 kg

Table 20. Percent of black rockfish landed that were sampled for tags.

	Sport				Commercial
Year	PCA1	PCA2	PCA3	PCA4	PCA1-4
1986	0.0%	77.4%	2.5%	41.0%	1.9%
1987	21.9%	86.0%	54.1%	48.5%	8.1%
1988	42.6%	85.3%	73.1%	57.0%	4.6%
1989	24.8%	73.7%	29.6%	57.4%	8.0%
1990	30.0%	65.2%	68.2%	48.3%	17.9%
1991	27.8%	66.0%	66.3%	41.3%	2.2%
1992	22.6%	58.8%	70.2%	35.8%	17.5%

Table 21. Total number of black rockfish sampled by year, days sampled and number of possible tags (positive metal detection) between 1998 and 2008.

Year	# of Days Sampled	# of Fish Sampled	Possible tags
1998	134	46951	14
1999	139	66253	79
2000	183	65276	365
2001	186	64440	260
2002	193	68475	423
2003	191	77622	612
2004	200	53385	305
2005	184	70482	338
2006	184	80416	493
2007	184	76782	843
2008	179	49337	485
Totals	1957	719419	4217

Table 22. Total number of black rockfish sampled by month and year between 1998 and 2008 from the recreational fishery in Westport (PCA2).

Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Totals
1998				9588	15660	14694	6702	307	46951
1999		4174	7730	13431	20563	14409	5946		66253
2000		1070	6489	13178	16144	19870	8525		65276
2001	440	4695	9906	17167	12233	13927	5939	133	64440
2002	781	4029	8292	12147	14517	17222	11487		68475
2003	905	7914	13190	14302	19788	15886	5637	0	77622
2004	1348	4909	12624	11200	13775	8184	1345	0	53385
2005	1978	6436	12265	15715	17396	14824	1868		70482
2006	4291	11158	18046	16628	16320	11685	2288		80416
2007	3212	10004	15191	18194	10527	17050	2604		76782
2008	872	3461	11228	9684	10932	12183	977		49337
Totals	13827	57850	114961	151234	167855	159934	53318	440	719419

Table 23. Total number of black rockfish landed by sport and commercial fisheries by year.

	Sport					
Year	**PCA1**	**PCA2**	**PCA3**	**PCA4**	**Comm**	**Total**
1998	11986	137311	5483	51766	4914	211460
1999	3395	141758	8483	42127	1371	197134
2000	5773	125556	8779	50257	1257	191622
2001	6340	106191	6276	42473	1943	163223
2002	6699	124991	7316	48513	343	187862
2003	12738	113778	8179	49287	1486	185468
2004	8420	120498	10088	69471	1029	209506
2005	8698	153493	20211	75286	2971	260659
2006	10914	174281	11495	49335	2057	248082
2007	10914	174281	11495	49335	0	246025
2008	10914	174281	11495	49335	0	246025
Total	96791	1546419	109300	577185	17371.43	2347066

Table 24. Estimated percent of black rockfish landed that were sampled for tags from PCA 2.

Year	**PCA2**
1998	34.2%
1999	46.7%
2000	52.0%
2001	60.7%
2002	54.8%
2003	68.2%
2004	44.3%
2005	45.9%
2006	46.1%
2007	44.1%
2008	28.3%

Table 25. Total number of tags recovered from all sources (sampled catch and volunteered) by punch card area between 1981 and 1997.

Recovery Year	PCA1	PCA2	PCA3	PCA4	Other	Total
1981	2	17				19
1982	23	36				59
1983	37	57		8		102
1984	30	24		3	1	58
1985	26	120		41	3	190
1986	24	217	5	34		280
1987	18	178	11	25		232
1988	21	156	6	33		216
1989	23	116	15	45		199
1990	31	143	23	22	1	220
1991	12	126	11	29	2	180
1992	10	52	17	29	5	113
1993	4	34	17	7		62
1994	2	17	2	1	1	23
1995	1	4	1			6
1996		2				2
1997		1				1
Total	264	1300	108	277	13	1,962

Note: 1995-1997 recoveries were from voluntary tag returns.

Table 26. Number of tags recovered from sampled catch by punch card area between 1981 and 1997.

Recovery	Sport				Commercial	
Year	PCA1	PCA2	PCA3	PCA4	PCA1-4	Total
1986	1	109	0	3	0	113
1987	2	121	0	5	1	129
1988	4	130	0	2	10	146
1989	2	59	0	1	7	69
1990	0	90	3	4	11	108
1991	3	51	3	3	5	65
1992	0	24	1	2	19	46
Total	12	584	7	20		676

Table 27. Total number of tags recovered by fishery between 1981 and 1997.

Recovery			Commercial			
Year	Sport	Unknown	Jig	Troll	Trawl	Total
1981	15	0	0	4	0	19
1982	18	0	3	8	30	59
1983	46	0	10	2	44	102
1984	27	0	1	0	30	58
1985	170	0	7	1	12	190
1986	260	1	6	0	13	280
1987	200	7	24	0	1	232
1988	171	4	27	3	11	216
1989	136	1	48	3	11	199
1990	167	2	33	4	14	220
1991	114	23	33	2	8	180
1992	62	5	30	5	11	113
1993	37	0	23	0	2	62
1994	19	0	3	0	1	23
1995	5	0	1	0	0	6
1996	2	0	0	0	0	2
1997	1	0	0	0	0	1
Total	1450	43	249	32	188	1962

Table 28. Percent of tags recovered from sampled catch by Punch Card Area.

Percent of tags recovered from sampled catch by Punch Card Area

Recovery Year	PCA1	PCA2	PCA3	PCA4
1986		51%		9%
1987	11%	68%	9%	20%
1988	19%	85%	33%	24%
1989	9%	52%	7%	13%
1990	0%	67%	22%	32%
1991	25%	44%	27%	14%
1992	20%	48%	65%	38%

Table 29. Tag recovery rate from sampled catch by year and PCA.

Recovery Year	PCA1	PCA2	PCA3	PCA4
1986		0.05%	0.00%	0.02%
1987	0.04%	0.05%	0.00%	0.03%
1988	0.04%	0.06%	0.00%	0.01%
1989	0.03%	0.03%	0.00%	0.01%
1990	0.00%	0.05%	0.10%	0.02%
1991	0.09%	0.04%	0.09%	0.02%
1992	0.00%	0.02%	0.02%	0.01%

Table 30. Tag recovery rate from total catch by year and PCA.

Recovery Year	PCA1	PCA2	PCA3	PCA4
1986	0.08%	0.08%	0.38%	0.11%
1987	0.09%	0.07%	0.58%	0.07%
1988	0.09%	0.06%	0.17%	0.09%
1989	0.10%	0.05%	0.46%	0.14%
1990	0.16%	0.06%	0.51%	0.06%
1991	0.10%	0.06%	0.21%	0.09%
1992	0.05%	0.03%	0.20%	0.05%

Table 31. Total number of tags recovered by release and recovery year.

Rel. Year	# of Rel.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	# 0f Rec
Unknown							1					19	6						26
1981	4739	19	53	50	32	8	8	9	6	6	4	3							198
1982	2541		6	28	6	2	2		1	1			2						48
1983	2033			24	17	13	3	2	3	1	1								64
1984	674				3	3	1	2	1										10
1985	4840					164	146	40	25	15	8	2	1						401
1986	5859						119	84	52	20	12	7	2		1				297
1987	5302							95	71	33	18	5	8	5					235
1988	7898								57	79	20	21	10	5	3	1	1		197
1989	9208									44	65	57	25	17	3	3			214
1990	8948										92	66	59	35	16	2	1	1	272
Total	52,042	19	59	102	58	190	280	232	216	199	220	180	113	62	23	6	2	1	1962

Table 32. Total number of tags recovered in sampled catch by release and recovery year.

Rel. Year	# of Rel.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	# 0f Rec
Unknown							1					19	6						26
1981	0.49%						5	6	5	3	1	3							23
1982	0.08%						1						1						2
1983	0.10%								1	1									2
1984	0.30%							1	1										2
1985	2.19%						57	24	15	6	3		1						106
1986	2.32%						49	38	31	9	5	3	1						136
1987	2.47%							58	47	10	10	1	5						131
1988	1.18%								46	30	7	4	5	1					93
1989	0.72%									10	31	13	12						66
1990	0.97%										51	19	17						87
Total		-	-	-	-	-	113	127	146	69	108	62	48	1	-	-	-	-	674

Table 33. Tag recovery rate by year of release and recovery year for all tags (reported and sampled)..

Rel. Year	# of Rel.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	Ave. Rate
Unknown																			
1981	4.18%	0.4%	1.1%	1.1%	0.7%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%							0.4%
1982	1.89%		0.2%	1.1%	0.2%	0.1%	0.1%		0.0%	0.0%			0.1%						0.2%
1983	3.15%			1.2%	0.8%	0.6%	0.1%	0.1%	0.1%	0.0%	0.0%								0.4%
1984	1.48%				0.4%	0.4%	0.1%	0.3%	0.1%										0.3%
1985	8.29%					3.4%	3.0%	0.8%	0.5%	0.3%	0.2%	0.0%	0.0%						1.0%
1986	5.07%						2.0%	1.4%	0.9%	0.3%	0.2%	0.1%	0.0%		0.0%				0.6%
1987	4.43%							1.8%	1.3%	0.6%	0.3%	0.1%	0.2%	0.1%					0.6%
1988	2.49%								0.7%	1.0%	0.3%	0.3%	0.1%	0.1%	0.0%	0.0%	0.0%		0.3%
1989	2.32%									0.5%	0.7%	0.6%	0.3%	0.2%	0.0%	0.0%			0.3%
1990	3.04%										1.0%	0.7%	0.7%	0.4%	0.2%	0.0%	0.0%	0.0%	0.4%

Table 34. Number of tag recoveries by release and recovery area across all years.

Release Area	Recovery Area																
	1C	1B	1A	3C	3B	3A	5C	5B	5A	6C	6B	6A	7C	7B	7A	8A	Other
1C	46	3	7	3													2
1B	13	40	37	3	3	2	2										3
3C			11	123	26	6							1				
3B			60	113	332	61	6	6					1	1			
3A			12	24	26	119	7	3	1	1							
5C			2	9	11	56	25	8									
5B			3	3	5	4	31	49	2			1					
6C			1	6	2	3		1	1	33		1	1			1	
6B			2	12	11	8		3		4	25	4	1				
6A			6	13	11	3	1	2		2	1	26	50	4	2		2
7C			4	8	10		1	1				3	11	21	2		3
7B	1		4	5	4	4	1	1				2	10	43	14	1	2
7A			2	2	3		1							1	49	1	1
8A					1					1				1	35	14	
Tptal	60	43	151	324	445	266	75	74	4	41	26	37	75	71	102	17	13

Table 35. Number of tag recoveries by tag type and year of release between 1998-2007. (ICWT=one Coded Wire Tag, 1CWT1PIT= one Coded Wire Tag and one PIT tag, 1PIT =one PIT tag and 2CWT = two Coded Wire Tags).

Release Year	1CWT	1CWT1PIT	1PIT	2CWT	Total
Tags	3	13		9	25
1998	10			228	238
1999				428	428
2000				457	457
2001				345	345
2002				496	496
2003				521	521
2004		54	68	294	416
2005		330			330
2006		466			466
2007				258	258
Totals	13	863	68	3036	3980

Table 36. Number of tag recoveries by month and year of recovery between 1998-2008..

	Month							
Year	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Totals**
1998				4	4	4	2	14
1999		2	2	7	18	42	5	76
2000			16	105	108	89	26	344
2001		2	19	73	60	51	24	229
2002	1	7	35	94	111	83	41	372
2003		49	82	77	171	174	26	579
2004	3	28	69	54	81	41	1	277
2005	4	18	42	58	71	96	3	292
2006	10	35	121	115	114	63	10	468
2007	7	35	146	296	122	200	26	832
2008	6	6	186	141	75	50	8	472
Totals	31	182	718	1024	935	893	172	3955

Table 37. Percent of tag recoveries by month and year of recovery between 1998-2008..

Year	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Totals**
1998				28.6%	28.6%	28.6%	14.3%	100%
1999		2.6%	2.6%	9.2%	23.7%	55.3%	6.6%	100%
2000			4.7%	30.5%	31.4%	25.9%	7.6%	100%
2001		0.9%	8.3%	31.9%	26.2%	22.3%	10.5%	100%
2002	0.3%	1.9%	9.4%	25.3%	29.8%	22.3%	11.0%	100%
2003		8.5%	14.2%	13.3%	29.5%	30.1%	4.5%	100%
2004	1.1%	10.1%	24.9%	19.5%	29.2%	14.8%	0.4%	100%
2005	1.4%	6.2%	14.4%	19.9%	24.3%	32.9%	1.0%	100%
2006	2.1%	7.5%	25.9%	24.6%	24.4%	13.5%	2.1%	100%
2007	0.8%	4.2%	17.5%	35.6%	14.7%	24.0%	3.1%	100%
2008	1.3%	1.3%	39.4%	29.9%	15.9%	10.6%	1.7%	100%
Average	1.2%	4.8%	16.1%	24.4%	25.2%	25.5%	5.7%	100%

Table 38. Tag recovery rate (# of tags recovered/# of fish sampled) by month across years.

Year	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Ave**
1998				0.04%	0.03%	0.03%	0.03%	0.03%
1999		0.05%	0.03%	0.05%	0.09%	0.29%	0.08%	0.10%
2000			0.25%	0.80%	0.67%	0.45%	0.30%	0.49%
2001		0.04%	0.19%	0.43%	0.49%	0.37%	0.40%	0.32%
2002	0.13%	0.17%	0.42%	0.77%	0.76%	0.48%	0.36%	0.44%
2003		0.62%	0.62%	0.54%	0.86%	1.10%	0.46%	0.70%
2004	0.22%	0.57%	0.55%	0.48%	0.59%	0.50%	0.07%	0.43%
2005	0.20%	0.28%	0.34%	0.37%	0.41%	0.65%	0.16%	0.34%
2006	0.23%	0.31%	0.67%	0.69%	0.70%	0.54%	0.44%	0.51%
2007	0.22%	0.35%	0.96%	1.63%	1.16%	1.17%	1.00%	0.93%
2008	0.69%	0.17%	1.66%	1.46%	0.69%	0.41%	0.82%	0.84%
Average	0.28%	0.29%	0.57%	0.66%	0.59%	0.54%	0.38%	0.47%

Table 39. Number of tag recoveries by release and recovery year.

Number of recoveries by release year and recovery year

Release Year	# of Releases	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Totals
Unreadible Tags				4		3	1	1			8	8	25
1998	2623	14	33	79	34	16	32	4	7	5	10	4	238
1999	3476		43	135	59	71	54	12	17	15	16	6	428
2000	2786			130	69	80	74	29	14	15	39	7	457
2001	3208				67	62	77	40	37	22	27	13	345
2002	4088					143	148	54	33	41	49	28	496
2003	6693						194	74	54	49	115	35	521
2004	6103							64	75	100	117	60	416
2005	3757								55	76	130	69	330
2006	6031									145	159	162	466
2007	5376										170	88	258
Total	44141	14	76	348	229	375	580	278	292	468	840	480	3980

Table 40. Tag recovery rate (# of tags recovered/# of releases) by release and recovery year.

Release Year	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
1998	0.5%	1.3%	3.1%	1.4%	0.6%	1.3%	0.2%	0.3%	0.2%	0.4%	0.2%
1999	1.2%	3.9%	1.8%	2.2%	1.7%	0.4%	0.5%	0.5%	0.5%	0.2%	
2000	4.7%	2.6%	3.1%	3.0%	1.2%	0.6%	0.6%	1.6%	0.3%		
2001	2.1%	2.0%	2.5%	1.3%	1.2%	0.8%	0.9%	0.5%			
2002	3.5%	3.8%	1.4%	0.9%	1.1%	1.3%	0.8%				
2003	2.9%	1.1%	0.8%	0.7%	1.7%	0.5%					
2004	1.0%	1.2%	1.7%	2.0%	1.0%						
2005	1.5%	2.1%	3.6%	2.0%							
2006	2.4%	2.7%	2.8%								
2007	3.2%	1.7%									
Average	2.3%	2.2%	2.3%	1.7%	1.2%	0.8%	0.6%	0.7%	0.3%	0.3%	0.2%

Table 41.Cumulative percent of tags recovered by release and recovery year.

Release Year	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
1998	0.5%	1.8%	4.8%	6.1%	6.7%	7.9%	8.1%	8.3%	8.5%	8.9%	9.1%
1999	1.2%	5.1%	6.8%	8.9%	10.4%	10.8%	11.2%	11.7%	12.1%	12.3%	
2000	4.7%	7.1%	10.0%	12.7%	13.7%	14.2%	14.8%	16.2%	16.4%		
2001	2.1%	4.0%	6.4%	7.7%	8.8%	9.5%	10.3%	10.8%			
2002	3.5%	7.1%	8.4%	9.2%	10.2%	11.4%	12.1%				
2003	2.9%	4.0%	4.8%	5.5%	7.3%	7.8%					
2004	1.0%	2.3%	3.9%	5.8%	6.8%						
2005	1.5%	3.5%	6.9%	8.8%							
2006	2.4%	5.0%	7.7%								
2007	3.2%	4.8%									
Average	2.3%	4.5%	6.7%	8.1%	9.1%	10.3%	11.3%	11.7%	12.4%	10.6%	9.1%

Table 42.Number of tag recoveries by release and recovery area when tag recovery area is known. Box indicates area of release.

Release Area	# of Releases	Recovery Area 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1	39			1																1
2	0																			0
3	789		3	11	2			4	1											21
4	1667			4	27	3	1	10	3	3		4	6	3	1					65
5	211							2		1	4	4								11
6	758			1	8	1	4	1	4	3	1		1		1					25
7	3228				16	9	13	115	43	18	10		3	9	2		1		1	240
8	5927		2	1	21	4	51	145	94	39	7	1	2	8	7	2	3		9	396
9	5210	1			9		8	21	31	53	24	3	4	3	5		1	2		165
10	3722				1		5	5	23	20	87	18	17	5	7					188
11	829				1		2	10	9	10	5	6	5	2				1		51
12	1373						1	1	1	10	4	15	11	5	5		2			55
13	6947		1				13	7	4	6	6	19	50	148	38	5	4	1	1	303
14	7477		1			1	2	9		4	9	9	50	52	124	9	1	1		272
15	3011			1	1		1	8	2	1	2	2	15	5	18	27	12			95
16	1451				1				1	1				2			17	5		27
17	2407							2			1			2	3			22		30
Totals	45046	1	7	19	87	18	101	340	216	169	160	81	164	244	211	43	41	32	11	1945

Table 43.Percent of tag recoveries by release and recovery area when tag recovery area is known.

Release Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1																		
2																		
3		14%	52%	10%			19%	5%										
4			6%	42%	5%	2%	15%	5%	5%		6%	9%	5%	2%				
5							18%		9%	36%	36%							
6			4%	32%	4%	16%	4%	16%	12%	4%		4%		4%				
7				7%	4%	5%	48%	18%	8%	4%		1%	4%	1%		0%		0%
8		1%	0%	5%	1%	13%	37%	24%	10%	2%	0%	1%	2%	2%	1%	1%		2%
9	1%			5%		5%	13%	19%	32%	15%	2%	2%	2%	3%		1%	1%	
10				1%		3%	3%	12%	11%	46%	10%	9%	3%	4%				
11				2%		4%	20%	18%	20%	10%	12%	10%	4%				2%	
12						2%	2%	2%	18%	7%	27%	20%	9%	9%		4%		
13		0%				4%	2%	1%	2%	2%	6%	17%	49%	13%	2%	1%	0%	0%
14		0%			0%	1%	3%		1%	3%	3%	18%	19%	46%	3%	0%	0%	
15			1%	1%		1%	8%	2%	1%	2%	2%	16%	5%	19%	28%	13%		
16				4%				4%	4%				7%			63%	19%	
17							7%			3%			7%	10%			73%	

Table 44. Tag recovery rates by release and recovery area where tag recovery area is known.

Recovery Area	# of Recoveries	Release area 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1																		
2	0																		
3	21			1.4%	0.1%			0.1%	0.0%										
4	65			0.5%	1.6%	1.4%	0.1%	0.3%	0.1%	0.1%		0.5%	0.4%	0.0%	0.0%				
5	11							0.1%		0.0%	0.1%	0.5%							
6	25			0.1%	0.5%	0.5%	0.5%	0.0%	0.1%	0.1%	0.0%		0.1%		0.0%				
7	240				1.0%	4.3%	1.7%	3.6%	0.7%	0.3%	0.3%		0.2%	0.1%	0.0%		0.1%		
8	396			0.1%	1.3%	1.9%	6.7%	4.5%	1.6%	0.7%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%		
9	165	2.6%			0.5%		1.1%	0.7%	0.5%	1.0%	0.6%	0.4%	0.3%	0.0%	0.1%		0.1%	0.1%	
10	188				0.1%		0.7%	0.2%	0.4%	0.4%	2.3%	2.2%	1.2%	0.1%	0.1%				
11	51				0.1%		0.3%	0.3%	0.2%	0.2%	0.1%	0.7%	0.4%	0.0%				0.0%	
12	55						0.1%	0.0%	0.0%	0.2%	0.1%	1.8%	0.8%	0.1%	0.1%		0.1%		
13	303						1.7%	0.2%	0.1%	0.1%	0.2%	2.3%	3.6%	2.1%	0.5%	0.2%	0.3%	0.0%	
14	272					0.5%	0.3%	0.3%		0.1%	0.2%	1.1%	3.6%	0.7%	1.7%	0.3%	0.1%	0.0%	
15	95			0.1%	0.1%		0.1%	0.2%	0.0%	0.0%	0.1%	0.2%	1.1%	0.1%	0.2%	0.9%	0.8%		
16	27				0.1%				0.0%	0.0%				0.0%			1.2%	0.2%	
17	30							0.1%			0.0%			0.0%	0.0%			0.9%	

1/ Only considers tags where tag recovery area is known

Table 45. Number of fish double tagged with CWT that died immediately following tagging by year and estimate of instantaneous tag loss rate for CWT.

Release Year	Release Tag Type	Recovery Tag Type	Lost a CWT Tag?	Count
2002	2CWT	1CWTL	Y	1
2003	2CWT	1CWTR	Y	1
2007	2CWT	1CWTL	Y	8
2007	2CWT	1CWTR	Y	8
2003	2CWT	2CWT	N	52
2004	2CWT	2CWT	N	22
2007	2CWT	2CWT	N	315
Total				407

Table 46. Number of double spaghetti tag recoveries by year of release, year of recapture and if tag loss was observed.

Release Year	Recapture Year	t(year)	Tag Missing No	Tag Missing Yes
1981	1981	0	1	
1983	1983	0	1	1
1985	1985	0	4	
1986	1986	0	4	
1987	1987	0	3	
1989	1989	0	3	
1990	1990	0	11	1
1981	1982	1	4	2
1982	1983	1		4
1983	1984	1	1	
1985	1986	1		1
1986	1987	1	7	4
1989	1990	1	7	2
1990	1991	1	4	9
1981	1983	2	6	4
1985	1987	2	1	
1986	1988	2	2	3
1987	1989	2	2	
1989	1991	2	2	4
1990	1992	2	5	8
1981	1984	3	3	2
1986	1989	3		1
1987	1990	3	1	
1989	1992	3		7
1990	1993	3	1	4
1981	1985	4	2	
1986	1990	4		2
1989	1993	4		1
1990	1994	4		4
1986	1991	5		1
1990	1995	5	1	
1981	1988	7		1
1981	1990	9		1
1982	1992	10		1
Totals			76	68

Table 47. Estimate of tag loss rate for black rockfish tagged with spaghetti tags.

Time of Recapture t(year)	Probability of tag loss ~	One Tag Retained mc	Both Tags Retained mAB
0-1	0.036	2	27
1-2	0.324	22	23
2-3	0.345	19	18
3-4	0.583	14	5
4-5	0.636	7	2
5-6		1	1
6-7		0	0
7-8		1	0
8-9		0	0
9-10		1	0
10-11		1	0

Based on Chapman-Fink-Bennett (CFB) Model

Table 48. Number of double CWT tag recoveries by years before recapture and whether tag loss was observed.

	Release	Recovered	Tag Missing	
t(year)	Tag Type	Tag Type	No	Yes
0	2CWT	1CWTL		23
0	2CWT	1CWTR		32
0	2CWT	2CWT	1164	
1	2CWT	1CWTL		23
1	2CWT	1CWTR		13
1	2CWT	2CWT	619	
2	2CWT	1CWTL		14
2	2CWT	1CWTR		18
2	2CWT	2CWT	434	
3	2CWT	1CWTL		16
3	2CWT	1CWTR		9
3	2CWT	2CWT	355	
4	2CWT	1CWTL		12
4	2CWT	1CWTR		13
4	2CWT	2CWT	317	
5	2CWT	1CWTL		5
5	2CWT	1CWTR		8
5	2CWT	2CWT	149	
6	2CWT	1CWTL		4
6	2CWT	1CWTR		3
6	2CWT	2CWT	84	
7	2CWT	1CWTL		2
7	2CWT	1CWTR		2
7	2CWT	2CWT	70	
8	2CWT	1CWTL		2
8	2CWT	1CWTR		1
8	2CWT	2CWT	25	
9	2CWT	1CWTR		2
9	2CWT	2CWT	14	
10	2CWT	2CWT	4	
Total			3235	202

Table 49. Number of fish recovered that shed a left or right CWT tag by year of recapture.

Comparison of CWT tag loss between left and right tags

Release	Recovered	t(year)										
Tag Type	Tag Type	0	1	2	3	4	5	6	7	8	9	Total
2CWT	1CWTL	14	23	14	16	12	5	4	2	2		92
2CWT	1CWTR	23	13	18	9	13	8	3	2	1	2	92

Note 1CWTL = one Coded Wire Tag Left and CWTR = one Coded Wire Tag Right

Table 50. Estimate of tag loss rate for black rockfish tagged with CWT.

Time of Recapture t(year)	Probability of tag loss (p*) p*=(mc/(mAB+mc)	Num. of fish that retained only one tag (mc)	Num. of fish that retained both tags (mAB)
0-1	0.023	37	775
1-2	0.028	36	619
2-3	0.036	32	434
3-4	0.034	25	353
4-5	0.038	25	317
5-6	0.042	13	148
6-7	0.040	7	84
7-8	0.028	4	70
8-9	0.057	3	25
9-10	0.067	2	14
10-11	0.000	0	4
Total		184	2843

Table 51. Number of PIT tag recoveries by recapture year and comparison of the number of fish that shed a tag or not.

	Release	Recovered	Tag Missing	
t(year)	Tag Type	Tag Type	No	Yes
0	1CWT1PIT	1CWT1PIT	207	
0	1CWT1PIT	1CWTL		4
0	1CWT1PIT	1PIT		1
1	1CWT1PIT	1CWT1PIT	248	
1	1CWT1PIT	1CWTL		3
1	1CWT1PIT	1PIT		1
2	1CWT1PIT	1CWT1PIT	302	
2	1CWT1PIT	1CWTL		2
2	1CWT1PIT	1PIT		1
3	1CWT1PIT	1CWT1PIT	72	
3	1CWT1PIT	1CWTL		7
4	1CWT1PIT	1CWT1PIT	3	
Total			832	19

Table 52. Estimate of tag loss rate for black rockfish tagged with PIT tags.

Time of Recapture t(year)	Probability of tag loss ~	Right or Left Tag Retained mc	Both Tags Retained mAB
0-1	0.012	5	207
1-2	0.008	4	248
2-3	0.005	3	302
3-4	0.046	7	72
4-5	0.000	0	3
		19	832

Table 53. Biomass trend data based on a range of tag-reporting rates and +/- 2CVs.

1999 Black Rockfish AD Model Results

	F45% + CV			F45% Mean			F45% - CV			F40% Mean			F50% Mean		
YEAR	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass	Total Biomass	Spawning Biomass	Catch Biomass
	75% Tag Reporting Rate														
1999	10,354	1,513	1,622	6,133	896	961	1,912	279	300	6,133	893	1,125	6,133	899	820
2000	9,384	1,239	1,426	5,559	734	844	1,733	229	263	5,414	701	959	5,683	762	739
2001	8,857	1,040	1,328	5,246	616	787	1,635	192	245	5,040	570	878	5,430	657	699
2002	8,588	914	1,279	5,087	542	758	1,586	169	236	4,856	491	839	5,297	588	679
2003	8,457	847	1,257	5,009	501	744	1,562	156	232	4,769	450	821	5,232	551	670
	50% Tag Reporting Rate														
1999	9,675	1,494	1,439	5,698	880	848	1,722	266	256	5,698	877	989	5,698	883	726
2000	8,581	1,283	1,252	5,054	755	737	1,527	228	223	4,926	725	836	5,165	782	647
2001	7,886	1,097	1,131	4,645	646	666	1,403	195	201	4,458	601	741	4,811	687	594
2002	7,479	959	1,062	4,405	565	625	1,331	171	189	4,195	514	689	4,597	612	563
2003	7,245	866	1,023	4,267	510	602	1,289	154	182	4,050	458	661	4,469	560	545
	25% Tag Reporting Rate														
1999	9,441	1,604	1,248	5,534	940	732	1,627	277	215	5,534	938	849	5,534	942	629
2000	8,402	1,548	1,118	4,925	907	655	1,448	267	193	4,812	879	741	5,025	932	576
2001	7,543	1,435	988	4,421	841	579	1,300	247	170	4,242	793	642	4,582	885	518
2002	6,915	1,301	894	4,053	763	524	1,192	224	154	3,843	702	573	4,247	819	475
2003	6,445	1,161	825	3,778	681	484	1,111	200	142	3,557	615	525	3,985	743	442

Table 54. Number of tagged black rockfish recovered by year between tag groups.

RelYear	Tag Type	Number Released	Percent of Release	Number of recoveries by year 2004	2005	2006	2007	2008
2004	**2CWT**	4,092	68.4%	73	47	66	82	50
2004	**1CWT1PIT**	858	14.4%	12	16	13	10	3
2004	**1PIT**	1,029	17.2%	1	12	21	27	7
Total		5,979		86	75	100	119	60

Table 55. Percent recovered by year among tag groups.

RelYear	Tag Type	Total # Recovered	Total % Recovered	Percent recovered by year 2004	2005	2006	2007	2008
2004	**2CWT**	318	7.8%	1.78%	1.15%	1.61%	2.00%	1.22%
2004	**1CWT1PIT**	54	6.3%	1.40%	1.86%	1.52%	1.17%	0.35%
2004	**1PIT**	68	6.6%	0.10%	1.17%	2.04%	2.62%	0.68%
Total		440		1.44%	1.25%	1.67%	1.99%	1.00%

Table 56. Number of tag releases by tag area in 2004.

Number of tag releases by area in 2004

Tag Type	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1CWT1PIT	76	102	14	59	123					132	123				258	887
1PIT						165	184	103			104	380	121			1057
2CWT	129	110	12	121	307	238	438	491	128	180	700	667	164	304	220	4209

Table 57. Number of tag recoveries by tag area in 2004.

Number of tag recoveries from the 2004 release group by area in 2004

Tag Type	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1CWT1PIT		1		2	3					1	4				1	12
1PIT												1				1
2CWT		5	3	9	15	14	5	5		4	2	6		3	2	73

Table 58. Percent of tag recoveries from the 2004 release group by area in 2004.

Percent of tag recoveries from the 2004 release group by area in 2004

Tag Type	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
1CWT1PIT		1.0%		3.4%	2.4%					0.8%	3.3%				0.4%	1.4%
1PIT												0.3%				0.1%
2CWT		4.5%	25.0%	7.4%	4.9%	5.9%	1.1%	1.0%		2.2%	0.3%	0.9%		1.0%	0.9%	1.7%

Table 59. Relationship between the PIT tag detection and speed the PIT tag was sent through the R-8000.

R-8000 PIT detection observations

Tag Speed	# Detected	Not Detected	% detected
Slow (2-3 sec)	2	8	20%
Medium (1-2 sec)	7	3	70%
Fast (<1 sec)	9	1	90%

Table 60. Results from testing interference between the Destron PIT tag detector and the R-8000.

Destron PIT detection observations out of 10 fish

Distance of PIT tag detector From R-8000	Slow	Medium	Fast	Highest % detected
0 inches	0	0	0	0%
3 inches	5	5	3	50%
6 inches	9	8	7	90%
12 inches	10	9	6	100%

Table 61. Results from testing CWT detectability using the R-8000.

Tag Detection Experiment 1
(10 single CWT, 90 untagged)

Category	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	exp
Control	91	90	90	90	90	90	91	90	90	90	90
R-8000	9	10	10	10	10	10	9	10	10	10	10
Destron											0
Allflex											0
chi-sq	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	
chi-sq	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	
chi-sq											
chi-sq											
Pcrit0.05=	3.841	for	*v=1*								

Table 62. Results from testing CWT and "coated" PIT tag detectability using the R-8000, Destron and Allflex PIT tag readers.

Tag Detection Experiment 2

(10 single CWT, 18 coated PIT only, 72 untagged)

Category	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	exp
Control	77	75	75	71	76	90	89	89	88	87	72
R-8000	10	10	11	11	10	10	10	10	10	10	28
Destron	11	12	11	16	11	0	1	1	2	3	18
Allflex	2	3	3	2	3	0	0	0	0	0	18
chi-sq	0.35	0.13	0.13	0.01	0.22	4.50	4.01	4.01	3.56	3.13	
chi-sq	11.57	11.57	10.32	10.32	11.57	11.57	11.57	11.57	11.57	11.57	
chi-sq	2.72	2.00	2.72	0.22	2.72	18.00	16.06	16.06	14.22	12.50	
chi-sq	14.22	12.50	12.50	14.22	12.50	18.00	18.00	18.00	18.00	18.00	

Table 63. Results from testing CWT and "coated" PIT both in combination with and without CWT tag detectability using the R-8000, Destron and Allflex PIT tag readers.

Tag Detection Experiment 3

(10 single CWT, 18 coated PIT only, 22 single CWT&coated PIT, 50 untagged)

Category	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	exp
Control	55	59	60	52	55						50
R-8000	33	33	33	33	33						32
Destron	12	8	7	14	12						40
Allflex	0	0	0	1	0						40
chi-sq	0.50	1.62	2.00	0.08	0.50	50.00	50.00	50.00	50.00	50.00	
chi-sq	0.03	0.03	0.03	0.03	0.03	32.00	32.00	32.00	32.00	32.00	
chi-sq	19.60	25.60	27.23	16.90	19.60	40.00	40.00	40.00	40.00	40.00	
chi-sq	40.00	40.00	40.00	38.03	40.00	40.00	40.00	40.00	40.00	40.00	

Table 64. Results from testing CWT, with and without coated PIT in combination with and without CWT tag detectability using the R-8000, Destron and Allflex PIT tag readers.

Tag Detection Experiment 4 [1/]

(18 coatedPITonly, 22 singleCWT&coatedPIT, 16 redPITonly, 11 singleCWT&redPIT, 23 untagged)

Category	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	exp
Control	22										23
R-8000	46	53	50	50	53						49
Destron "coated" PIT only	18	17	24	18	21						40
Destron CWT&"coated" PIT	22	26	21	26	26						27
Allflex "red" PIT	2	1	0	1	1						40
Allflex "red" PIT & CWT	8	5	10	6	10						27
chi-sq	0.04	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	
chi-sq	0.18	0.33	0.02	0.02	0.33	49.00	49.00	49.00	49.00	49.00	
chi-sq	12.10	13.23	6.40	12.10	9.03	40.00	40.00	40.00	40.00	40.00	
chi-sq	0.93	0.04	1.33	0.04	0.04	27.00	27.00	27.00	27.00	27.00	
chi-sq	36.10	38.03	40.00	38.03	38.03	40.00	40.00	40.00	40.00	40.00	
chi-sq	13.37	17.93	10.70	16.33	10.70	27.00	27.00	27.00	27.00	27.00	

1/ Allflex "red" PIT tags are uncoated

Table 65. Results from testing Destron detectability among several different tag types and tag combinations.

All detections with Destron
(18 coatedPITonly, 22 singleCWT&coatedPIT, 16 redPITonly, 11 singleCWT&redPIT, 23 untagged)

Experiment 5	Trial1	Trial2	Trial3	Trial4	Trial5	Expected
coatedPIT&CWTx1	10	12	13	10	15	22
coatedPITonly	8	6	12	8	7	18
redPIT&CWTx1	10	11	7	11	10	11
redPITonly	12	15	13	15	16	16
Chi-sq	6.55	4.55	3.68	6.55	2.23	
Chi-sq	5.56	8.00	2.00	5.56	6.72	
Chi-sq	0.09	0.00	1.45	0.00	0.09	
Chi-sq	1.00	0.06	0.56	0.06	0.00	Mean
Detection rate	45%	55%	59%	45%	68%	55%
Detection rate	44%	33%	67%	44%	39%	46%
Detection rate	91%	100%	64%	100%	91%	89%
Detection rate	75%	94%	81%	94%	100%	89%

Table 66. Comparison of tag recovery rates from 2004 tag releases by tag type.

RelYear	Tag Type	Number Released	Percent of Release	Number of recoveries by year 2004	2005	2006	2007	2008
2004	**2CWT**	4,092	68.4%	73	47	66	82	50
2004	**1CWT1PIT**	858	14.4%	12	16	13	10	3
2004	**1PIT**	1,029	17.2%	1	12	21	27	7
Total		5,979		86	75	100	119	60

RelYear	Tag Type	Total # Recovered	Total % Recovered	Percent recovered by year 2004	2005	2006	2007	2008
2004	**2CWT**	318	7.8%	1.78%	1.15%	1.61%	2.00%	1.22%
2004	**1CWT1PIT**	54	6.3%	1.40%	1.86%	1.52%	1.17%	0.35%
2004	**1PIT**	68	6.6%	0.10%	1.17%	2.04%	2.62%	0.68%
Total		440		1.44%	1.25%	1.67%	1.99%	1.00%

Table 67. Number of tag releases by associated injuries.

Hook Blood	Gut Tight	Membrane Bulg	Eye Bulg	Eye Air	Blood	Hit Deck	Total
N	N	N	N	N	N	N	7411
N	N	N	N	N	N	Y	103
N	N	N	N	N	Y	N	83
N	N	N	N	Y	N	N	35
N	N	N	N	Y	N	Y	1
N	N	N	Y	N	N	N	60
N	N	N	Y	Y	N	N	9
N	N	N	Y	Y	N	Y	2
N	N	Y	N	N	N	N	23
N	N	Y	Y	N	N	N	1
N	Y	N	N	N	N	N	6006
N	Y	N	N	N	N	Y	50
N	Y	N	N	N	Y	N	33
N	Y	N	N	N	Y	Y	1
N	Y	N	N	Y	N	N	72
N	Y	N	N	Y	N	Y	1
N	Y	N	N	Y	Y	N	2
N	Y	N	Y	N	N	N	366
N	Y	N	Y	N	N	Y	1
N	Y	N	Y	N	Y	N	1
N	Y	N	Y	Y	N	N	102
N	Y	N	Y	Y	N	Y	1
N	Y	Y	N	N	N	N	80
N	Y	Y	N	N	Y	N	1
N	Y	Y	N	Y	N	N	1
N	Y	Y	N	Y	N	Y	1
N	Y	Y	Y	N	N	N	20
N	Y	Y	Y	Y	N	N	4
Y	N	N	N	N	N	N	334
Y	N	N	N	N	N	Y	11
Y	N	N	N	N	Y	N	12
Y	N	N	N	Y	N	N	3
Y	N	N	Y	N	N	N	5
Y	N	Y	N	N	N	N	3
Y	Y	N	N	N	N	N	273
Y	Y	N	N	N	N	Y	4
Y	Y	N	N	N	Y	N	4
Y	Y	N	N	Y	N	N	5
Y	Y	N	Y	N	N	N	17
Y	Y	N	Y	Y	N	N	2
Y	Y	N	Y	Y	N	Y	1
Y	Y	Y	N	N	N	N	14
Y	Y	Y	N	N	Y	N	1
Y	Y	Y	Y	N	N	N	4

Table 68. Summary of tag releases by associated injuries and percent that died immediately following tagging.

Observed Trauma By Injury Category for fish that survived tagging						Number of	Number of Live	Number of Dead	% Total
Hook Blood	Gut Tight	Membrane Bulg	Eye Bulg	Eye Air	Blood	Hit Deck	Tag Releases	Fish Recovered	Mortality
N	N	N	N	N	N	0	7411	52	0.7%
N	N	N	Y	N	N	1	60	1	1.6%
N	Y	N	N	N	N	1	6006	143	2.3%
N	Y	N	Y	N	N	2	367	15	3.9%
N	Y	N	N	Y	N	2	73	4	5.2%
N	N	N	Y	Y	N	2	11	1	8.3%
N	N	Y	N	N	N	1	23	4	14.8%
N	N	Y	Y	Y	N	3	4	1	20.0%
N	Y	Y	N	N	N	2	80	63	44.1%
N	Y	Y	Y	N	N	3	20	17	45.9%
N	Y	Y	N	Y	N	3	2	3	60.0%
N	N	Y	Y	N	N	2	1	2	66.7%
N	Y	Y	Y	Y	N	4	4	16	80.0%
							14062	322	2.2%

Table 69. Number, percent of releases and percent recovered as dead immediately following tagging for tagged fish released without injury, a single injury or multiple injuries.

# of Injuries	# of Releases	% of Releases	# recovered as Dead
None	7463	51.9%	0.7%
1	6237	43.4%	2.4%
2	617	4.3%	13.8%
3 or more	64	0.4%	57.8%

Table 70. Number of black rockfish tagged and released and then recovered as dead by year and tag type. Note that tag mortalities recovered in years prior to 2005 were (mostly) removed from both the tag recovery and release databases and record was not maintained.

Number of mortality tags by tag type and release year

Release Year	1CWT	1CWT1PIT	1PIT	2CWT	Total
1998				5	5
1999				3	3
2000				3	3
2001				2	2
2002				1	1
2003				60	60
2004	1	24	8	19	52
2005		192		1	193
2006		258			258
2007				328	328
Totals	1	474	8	422	905

Table 71. Number of black rockfish tagged and released and then recovered as dead by year and tag type and separated into depth bin.

Depth (m)	# Live	# Dead	Total	%Dead
30-40	1218	23	1241	2%
40-50	455	4	459	1%
50-60	355	13	368	4%
60-70	553	23	576	4%
70-80	912	28	940	3%
80-90	2066	141	2207	6%
90-100	747	44	791	6%
100-110	1106	70	1176	6%
110-120	621	34	655	5%
120-130	749	102	851	12%
>130	351	39	390	10%
	9133	521	9654	

Table 72. Number of tagged fish released by release year and by the number of observed injuries associated with capture.

				Number of releases by the number of injuries					
MortalityTags	RelYear	Total # of Releases	# of Injury Observations	0	1	2	3	4	5
N	2004	6103	1794	1507	270	17			
N	2005	3757	3428	2052	942	310	94	24	6
N	2006	6031	5568	2905	1860	589	167	42	5
N	2007	5376	5123	1791	2542	591	150	49	

Table 73. Number of tagged fish recovered by release year and number of observed injuries associated with capture.

				Number of recoveries by the number of releases					
MortalityTags	RelYear	Recovered?	# of Recoveries	0	1	2	3	4	5
N	2004	Y	118	95	23				
N	2005	Y	328	239	62	20	6	1	
N	2006	Y	463	241	134	66	22		
N	2007	Y	253	108	116	27	2		

Table 74. Recovery rate of tagged fish by release year and number of observed injuries associated with capture.

				Recovery rate by the number of releases					
MortalityTags	RelYear	# of Years observed For Recovery	Recovery Rate	0	1	2	3	4	5
N	2004	4	6.58%	6.30%	8.52%				
N	2005	3	9.57%	11.65%	6.58%	6.45%	6.38%	4.17%	
N	2006	2	8.32%	8.30%	7.20%	11.21%	13.17%		
N	2007	1	4.94%	6.03%	4.56%	4.57%	1.33%		

Table 75. Number of fish tagged and released with OTC and comparison of tag release and recovery data between OTC-injected (A) and non-injected black rockfish (B) tagged aboard fisheries vessels.

A.

Year Released	Total Number Released	Year of Recovery 1981	1982	1983	1984	1985	1986	1987-1991	Total Recovered	Percent Recovered
1981	1068	1	5	3	1	0	0	1	11	1.03%
1982	375	-	0	2	1	0	0	0	3	0.80%
1983	132	-	-	0	0	0	0	0	0	
Totals	1575								14	

B.

Year Released	Total Number Released	Year of Recovery 1981	1982	1983	1984	1985	1986	1987-1991	Total Recovered	Percent Recovered
1981	1435	1	18	12	5	1	0	1	39	2.72%
1982	1556	-	3	14	0	1	1	0	19	1.22%
1983	1686	-	-	16	16	13	3	7	55	3.26%
Totals	4677								113	

Table 76. Comparison of tag release and recovery data between OTC-injected (A) and non-injected black rockfish (B) tagged aboard sport charter vessels.

A.

Year Released	Total Number Released	Year of Recovery 1981	1982	1983	1984	1985	1986	1987-1991	Total Recovered	Percent Recovered
1981	0	0	0	0	0	0	0	0	0	
1982	299	-	3	7	3	1	0	1	15	5.02%
1983	0	-	-	0	0	0	0	0	0	
Totals	299								15	

B.

Year Released	Total Number Released	Year of Recovery 1981	1982	1983	1984	1985	1986	1987-1991	Total Recovered	Percent Recovered
1981	1942	16	25	25	21	5	8	19	119	6.13%
1982	141	-	0	3	2	0	1	0	6	4.26%
1983	101	-	-	0	6	0	0	0	6	5.94%
Totals	2184								113	

Table 77. Release and recovery information for recovered tagged black rockfish which had been injected with oxytetracycline (OTC).

Release Date	Recovery Date	Days at Liberty	Expected Number of Annuli	Annuli Formed After Tagging	Age at Recapture in Years
May 14, 1982	July 17, 1982	64	0	0	6
August, 1981	September 5, 1982	389	1	1	10
August, 1981	September 25, 1982	408	1	1	10
May 14, 1982	July 7, 1983	419	1	1	13
May 14, 1982	August 4, 1983	447	1	1	11
Aug. 3, 1982	May 21, 1984	656	2	2	19
May 24, 1981	March 9, 1983	662	2	2	12
May 14, 1982	April 7, 1984	693	2	2	9
May 14, 1982	April 9, 1984	695	2	2	10
May 14, 1982	May 24, 1984	740	2	2	11
Aug 12, 1981	May 6, 1984	997	3	3	14
May 14, 1982	March 2, 1985	1,023	3	3	11
May 14, 1982	July 10, 1989	2,614	7	7	16

Table 78. Distance traveled frequency of occurrence, percent of recoveries and cumulative percent of recoveries for fish released since 2005.

Distance Traveled (km)	Frequency	Percent	Cumulative Percent
0-10	1096	75%	75%
10-20	146	10%	85%
20-30	40	3%	88%
30-40	25	2%	90%
40-50	30	2%	92%
50-60	15	1%	93%
60-70	11	1%	94%
70-80	17	1%	95%
80-90	22	2%	96%
90-100	28	2%	98%
100+	27	2%	100%

Table 79. Time at liberty, frequency, mean distance traveled, percent of recoveries and cumulative percent of recoveries for fish released since 2005.

Liberty (year)	Frequency	Mean Distance Traveled (km)	Percent	Cumulative Percent
< 30 days	147	5	9%	9%
< 1 year	495	10	31%	40%
1-2	465	20	29%	69%
2-3	252	28	16%	84%
3-4	136	39	8%	93%
4-5	71	35	4%	97%
5-6	30	21	2%	99%
6-7	16	53	1%	100%
7-8	2	58	0%	100%
8-9	2	55	0%	100%
Total	1616			

Table 80. Average distance traveled by release and recovery year.

Release Year	Recovery Year 85	86	87	88	89	90	91	92	93	94
1985	7	11	5	23	21					
1986		3	8	20	36					
1987			5	21	40	33				
1988				4	19	30	44			
1989					7	32	36	61	35	
1990						7	32	42	41	50

Average distance traveled (km) estimated for strata with >10 recaptures

Table 81. Total number of releases by geographic area between 1981 and 1990

Total Number of Releases by Area of Release

Year	Cape Falcon	Col. River	Grays Harbor	Cape Elizabeth	La Push	Neah Bay	Total
1981	0		4052	687	0	0	4739
1982	0		450	1721	0	370	2541
1983	1199		109	0	0	725	2033
1984	0		0	0	0	674	674
1985	1283		2216	193	0	1148	4840
1986	784		1085	1188	1908	894	5859
1987	1075		1036	321	1939	931	5302
1988	1085		1364	1362	2739	1348	7898
1989	1414		1279	1161	2911	2443	9208
1990	1038		1114	1330	3602	1864	8948
Total	7878		12705	7963	13099	10397	52042
% of Total	15%		24%	15%	25%	20%	

Table 82. Total number of recoveries by geographic release area and year of release.

Total Number of Recoveries by Area of Release

Year	Cape Falcon	Col. River	Grays Harbor	Cape Elizabeth	La Push	Neah Bay	Total
1981			198				198
1982			22	17		9	48
1983	55		6			3	64
1984						10	10
1985	33		297	2		69	401
1986	17		165	54	41	20	297
1987	17		143	8	40	27	235
1988	15		65	33	36	48	197
1989	19		57	34	59	45	214
1990	15		73	69	73	42	272
Total Tags	171		1026	217	249	273	1936
% of rec by	2.2%		13.0%	2.8%	3.2%	3.5%	
Rec Rate	**2.2%**		**8.1%**	**2.7%**	**1.9%**	**2.6%**	**3.7%**

Table 83. Number of recoveries made south of Cape Falcon by release site and recovery year.

Recoveries made south of Cape Falcon by Release

	Recovery Year						
RelAreaName	**1984**	**1985**	**1990**	**1991**	**1992**	**1994**	**Total**
Cape Falcon	**1**	**3**				**1**	**5**
La Push					**2**		**2**
Neah Bay			**1**	**2**	**3**		**6**
Total	**1**	**3**	**1**	**2**	**5**	**1**	**13**

Table 84. Fate of Cape Falcon releases by release year and percent of total recoveries by geographic area.

Fate of Cape Falcon Releases (% of recoveries)

Year	Cape Falcon	Col. River	Grays Harbor	Cape Elizabeth	La Push	Neah Bay	Total
1981							
1982							
1983	42.3%	53.8%	3.8%				1
1984							
1985	81.3%	12.5%	6.3%				1
1986	75.0%	12.5%	12.5%				1
1987	81.3%	6.3%	6.3%	6.3%			1
1988	80.0%	13.3%	6.7%				1
1989	55.6%	33.3%	11.1%				1
1990	80.0%	6.7%	6.7%	6.7%			1
Total Tags	107	44	11	2	0	0	164
% of rec by	65.2%	26.8%	6.7%	1.2%	0.0%	0.0%	

Table 85. Fate of Grays Harbor releases by release year and percent of total recoveries by geographic area.

Fate of Grays Harbor Releases (% of recoveries)

Year	Cape Falcon	Col. River	Grays Harbor	Cape Elizabeth	La Push	Neah Bay	Total
1981		25.4%	71.0%	3.6%			1
1982		40.9%	59.1%				1
1983			100.0%				1
1984							0
1985		6.1%	93.6%			0.3%	1
1986		0.6%	97.5%	1.8%			1
1987		1.4%	92.2%	5.0%	0.7%	0.7%	1
1988		1.6%	95.2%	3.2%			1
1989		5.4%	94.6%				1
1990			94.4%	5.6%			1
Total Tags	0	83	901	23	1	2	1010
% of rec by	0.0%	8.2%	89.2%	2.3%	0.1%	0.2%	

Table 86. Fate of Cape Elizabeth releases by release year and percent of total recoveries by geographic area.

Fate Cape Elizebeth Releases (% of Recoveries)

Year	Cape Falcon	Col. River	Grays Harbor	Cape Elizabeth	La Push	Neah Bay	Total
1981			100.0%				1
1982		12.5%	12.5%	68.8%	6.3%		1
1983							0
1984							0
1985			100.0%				1
1986		3.9%	27.5%	68.6%			1
1987			12.5%	87.5%			1
1988			97.0%	3.0%			1
1989			54.5%	45.5%			1
1990		1.4%	26.1%	72.5%			1
Total Tags	0	5	88	50	1	0	144
% of rec by	0.0%	3.5%	61.1%	34.7%	0.7%	0.0%	

Table 87. Fate of La Push releases by release year and percent of total recoveries by geographic area.

Fate of La Push Releases (% of recoveries)

Year	Cape Falcon	Col. River	Grays Harbor	Cape Elizabeth	La Push	Neah Bay	Total
1981							0
1982							0
1983							0
1984							0
1985							0
1986		2.4%	7.3%	4.9%	24.4%	61.0%	1
1987		5.1%	33.3%	2.6%	48.7%	10.3%	1
1988		8.3%	27.8%	5.6%	38.9%	19.4%	1
1989		3.4%	25.4%	3.4%	45.8%	22.0%	1
1990		1.4%	40.0%	1.4%	42.9%	14.3%	1
Total Tags	0	9	69	8	100	59	245
% of rec by	0.0%	3.7%	28.2%	3.3%	40.8%	24.1%	

Table 88. Fate of Neah Bay releases by release year and percent of total recoveries by geographic area.

Fate of Neah Bay Releases (% of recoveries)

Year	Cape Falcon	Col. River	Grays Harbor	Cape Elizabeth	La Push	Neah Bay	Total
1981							0
1982						100.0%	1
1983						100.0%	1
1984			20.0%			80.0%	1
1985					1.4%	98.6%	1
1986	5.0%	15.0%				80.0%	1
1987		3.7%	18.5%			77.8%	1
1988		2.1%	23.4%	2.1%		72.3%	1
1989		4.7%	27.9%	9.3%	7.0%	51.2%	1
1990		7.9%	18.4%		5.3%	68.4%	1
Total Tags	1	10	37	5	6	207	266
% of rec by	0.4%	3.8%	13.9%	1.9%	2.3%	77.8%	

Table 89. Summary of the year, the number of fish tagged, sampled, returned with tag on the right, tag on the left, double tag, the estimated population size and variance, the adjusted number of tag returns with tag loss, the estimated population size with tag loss adjustment and variance.

Year	n_1	n_2	m	m_r	m_l	m_d	$\hat{N}$	$\mathrm{Var}(\hat{N})$	$\ddot{\hat{m}}$	$\hat{\ddot{N}}$	$\mathrm{Var}(\hat{\ddot{N}})$
1998	2456	46951	14	1	1	12	7.69E+06	3.67E+12	14.08	7.65E+06	4.53E+12
1999	3479	66253	43	1	0	42	5.24E+06	6.02E+11	43.01	5.24E+06	6.46E+11
2000	2789	65276	130	3	5	122	1.39E+06	1.39E+10	130.13	1.39E+06	1.53E+10
2001	3210	64440	68	2	1	65	3.00E+06	1.26E+11	68.03	3.00E+06	1.35E+11
2002	4089	68475	143	1	1	141	1.94E+06	2.51E+10	143.01	1.94E+06	2.66E+10
2003	6747	77622	246	1	8	237	2.12E+06	1.74E+10	246.09	2.12E+06	1.86E+10
2004	4209	53385	74	1	1	72	3.00E+06	1.16E+11	74.01	3.00E+06	1.23E+11
2005	3913	70482	54	0	0	54	5.02E+06	4.43E+11	54.00	5.02E+06	4.66E+11

8. Figures

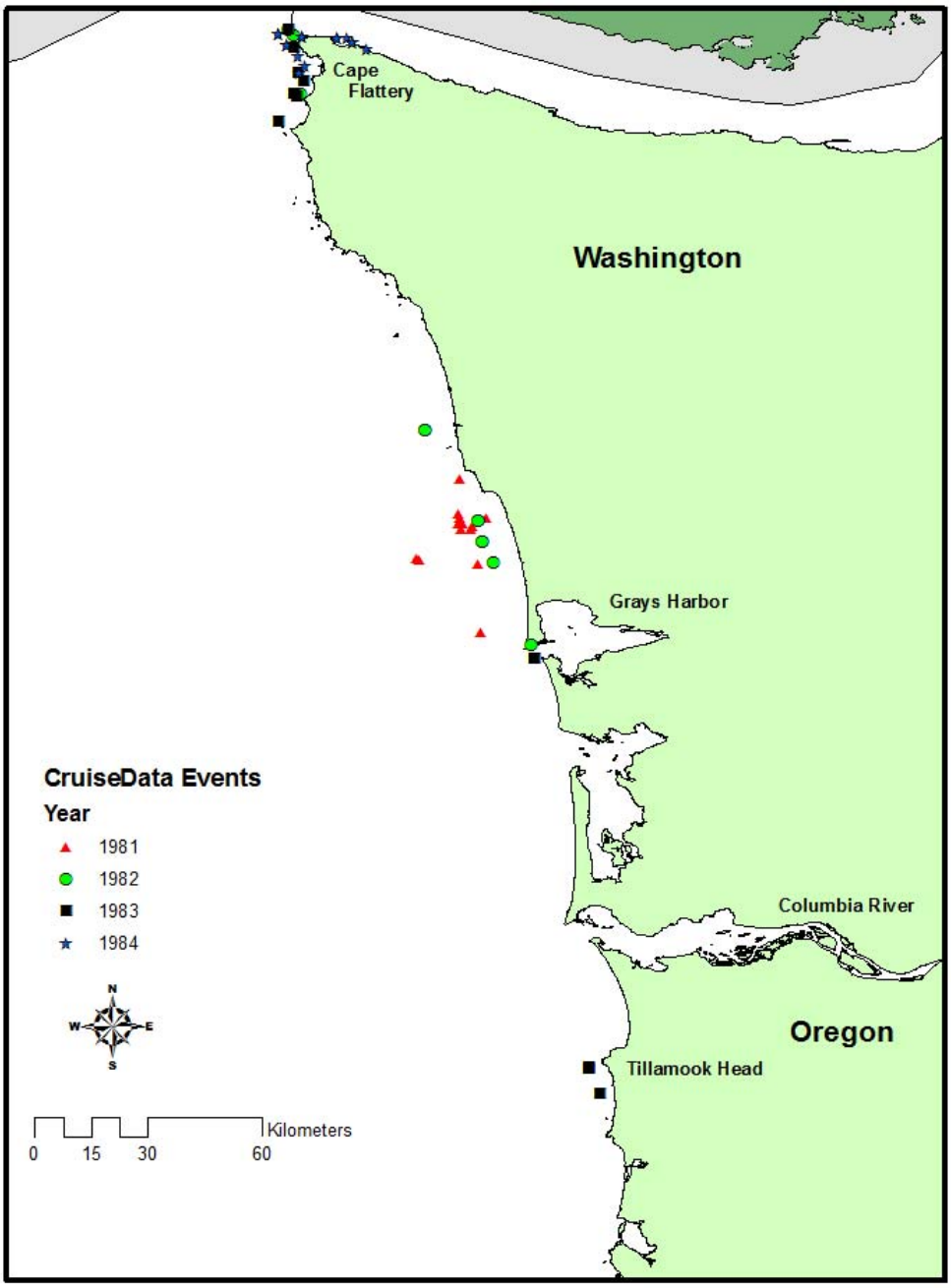

Figure 1. Tag release sites 1981-1984.

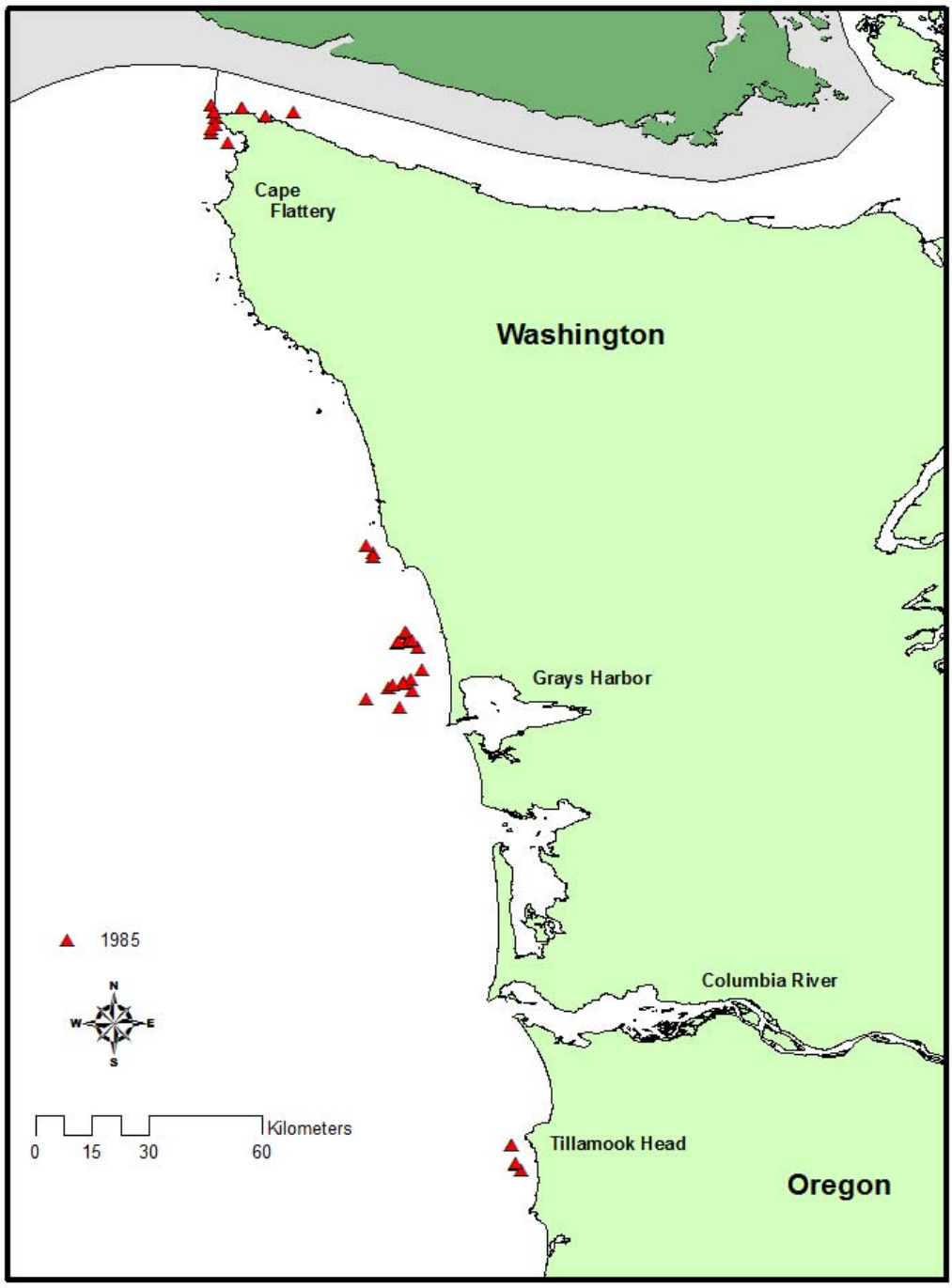

Figure 2. Tag release sites in 1985.

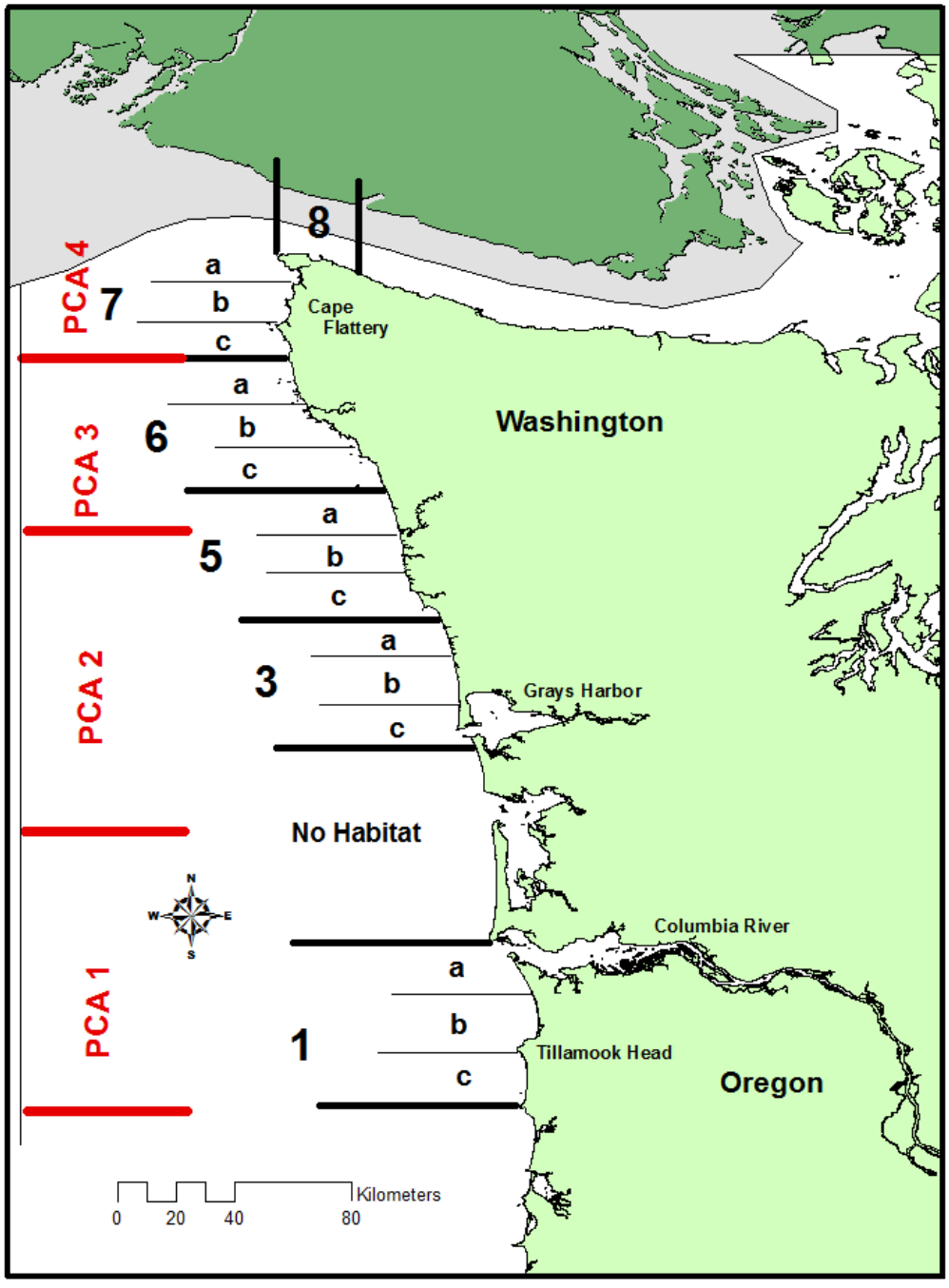

Figure 3. Tagging strata (1986-1990) used to distribute tagging effort overlaid with Washington Department of Fish coastal Salmon Punch Card Areas.

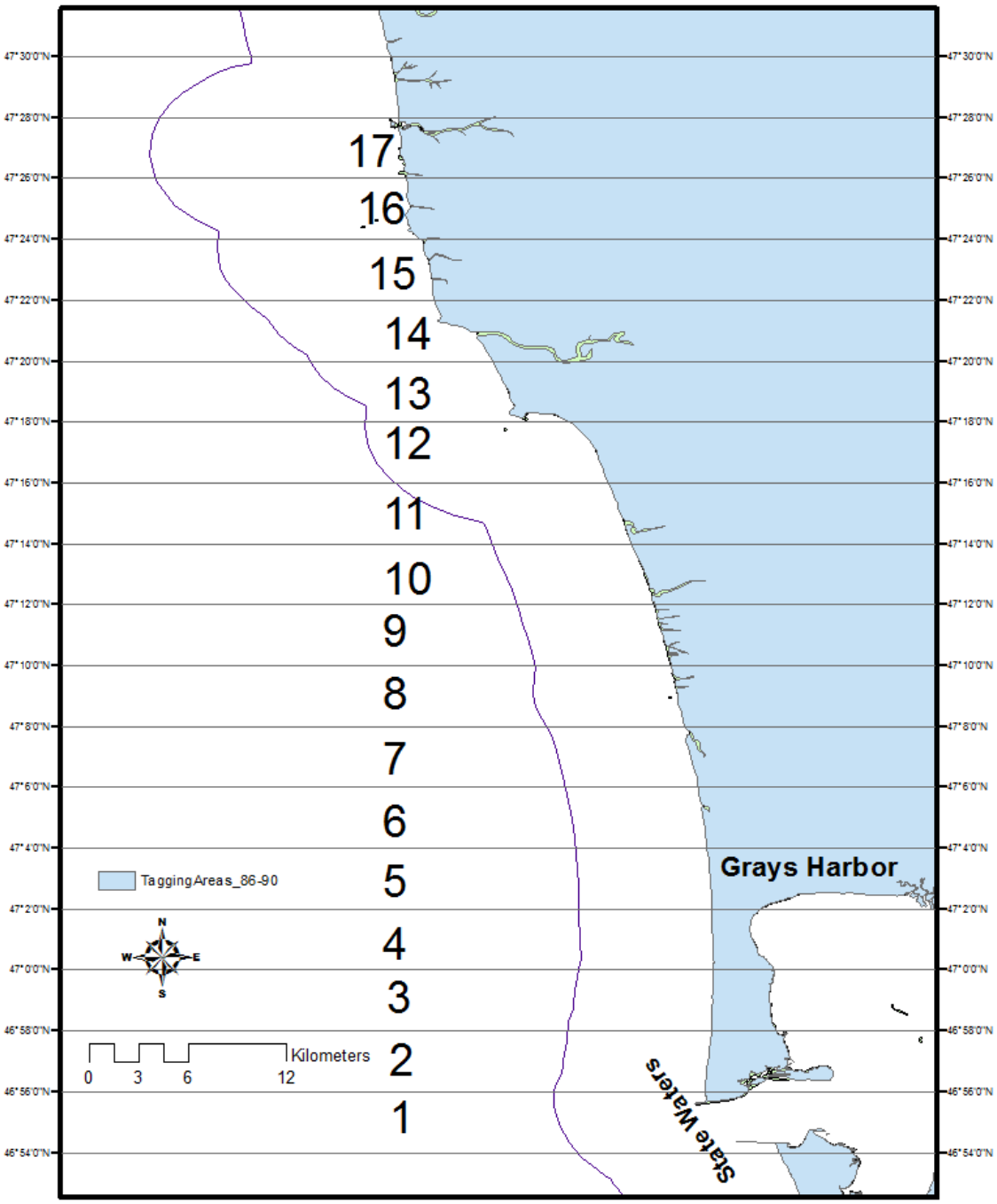

Figure 4. Tagging strata (1998-2008) used to distribute tagging effort off central Washington Coast proportional to the number of pinnacles (green dots).

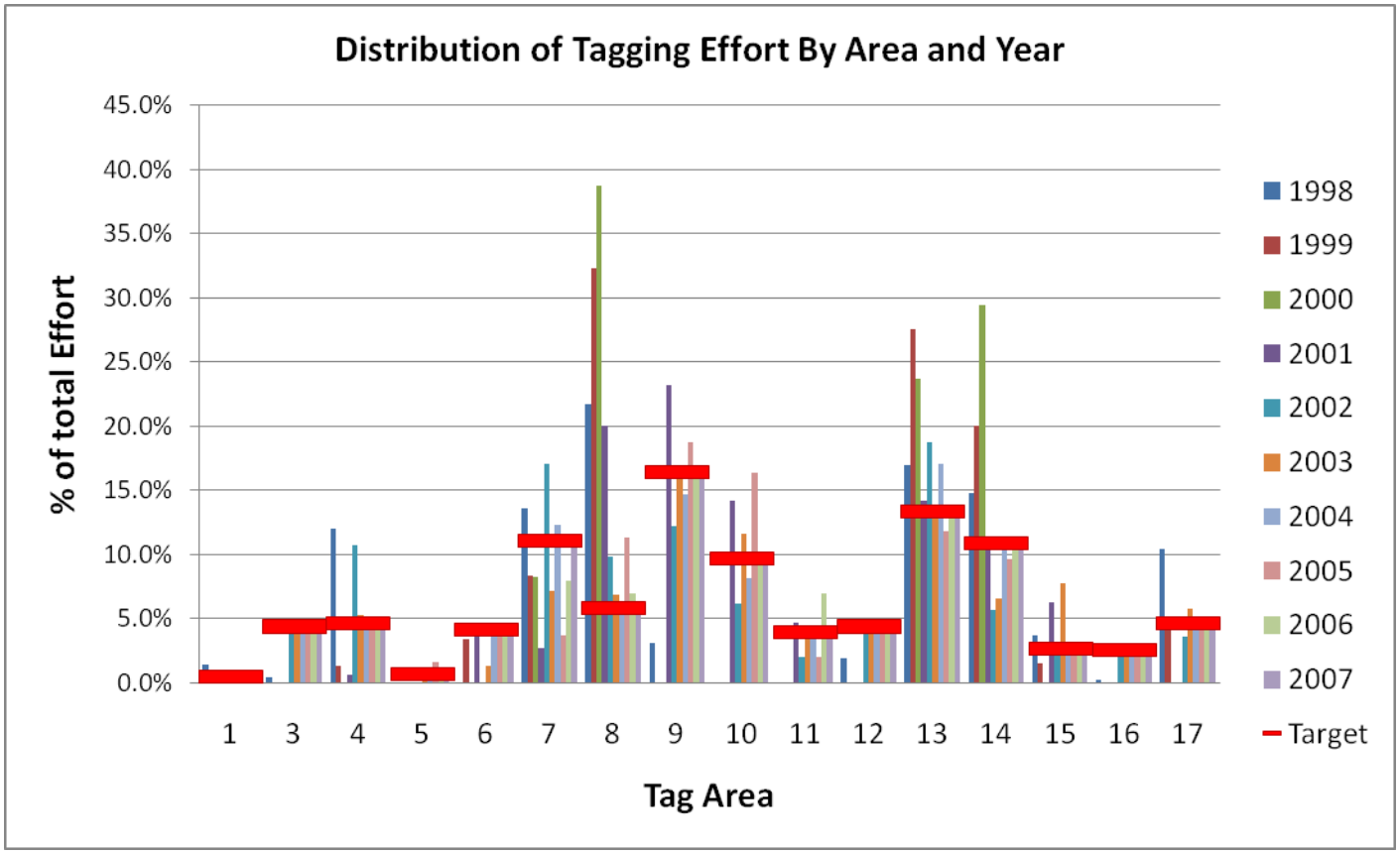

Figure 5. Distribution of total tagging effort between 1998 and 2007.

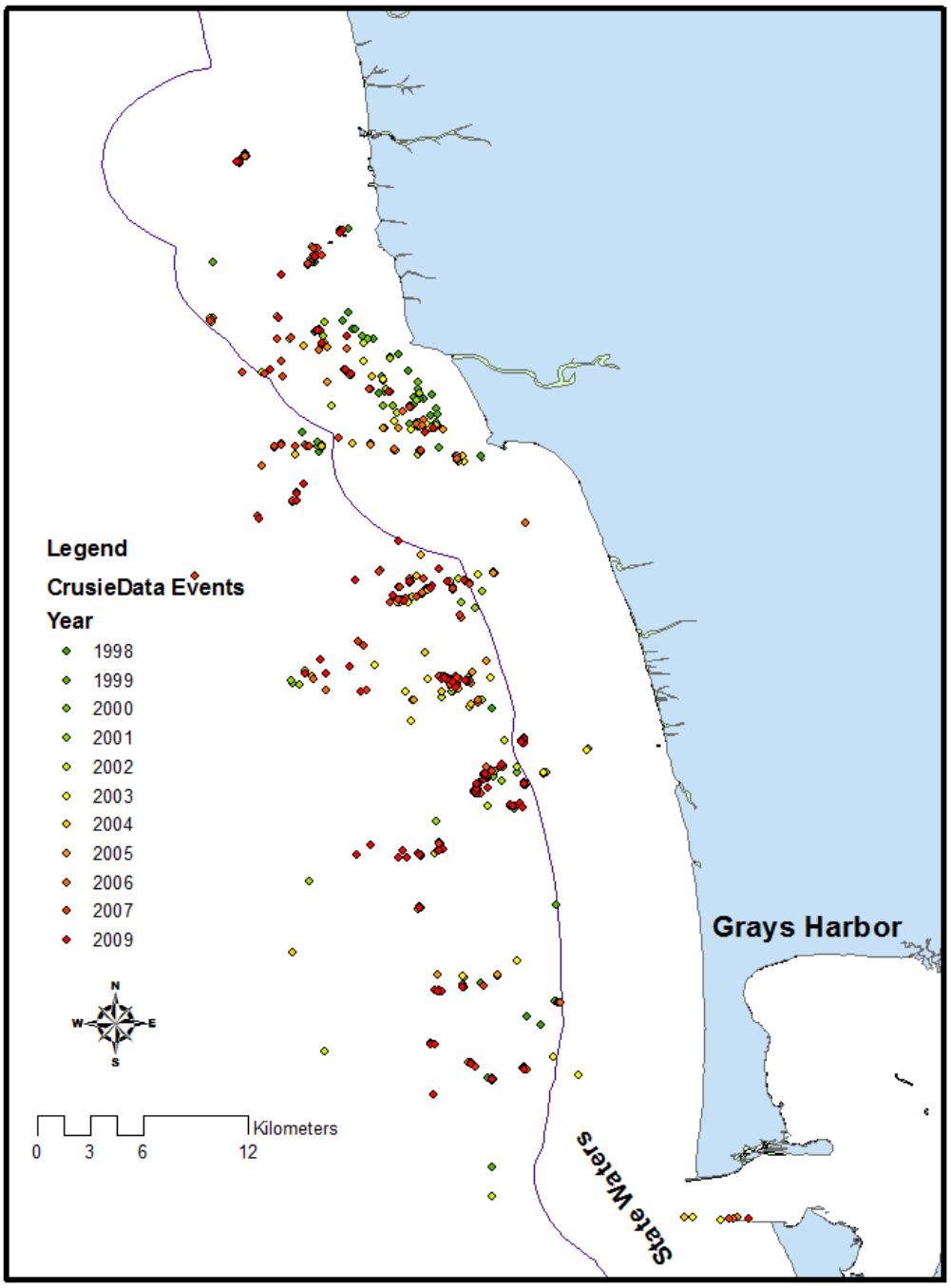

Figure 6. Tag release sites for all tagged fish between 1998 and 2008.

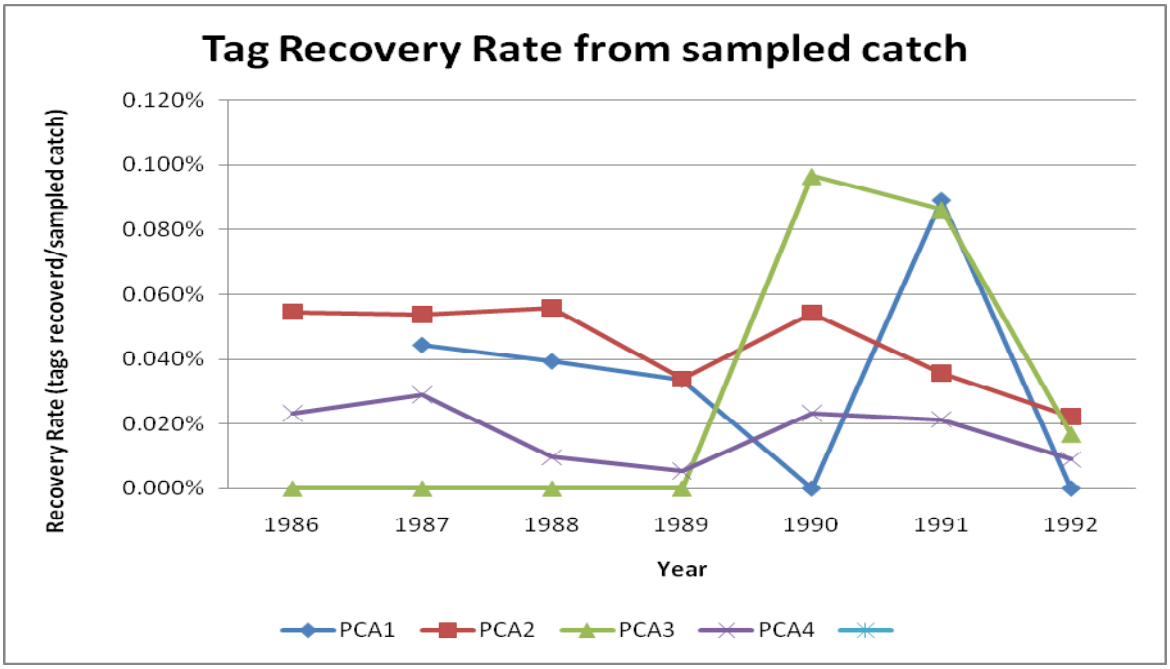

Figure 7. Comparison of tag recovery rates from sampled catch by year and Punch Card Area (PCA)

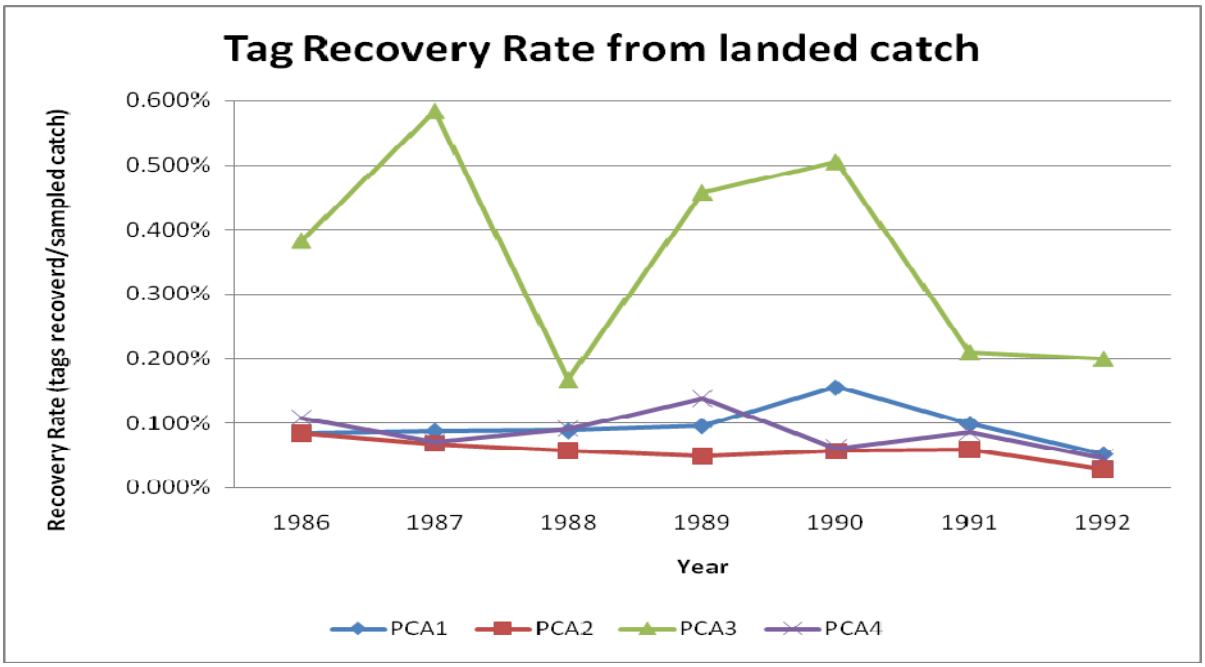

Figure 8. Comparison of tag recovery rates from all recovered tags (from sampling and volunteered) by year and Punch Card Area (PCA).

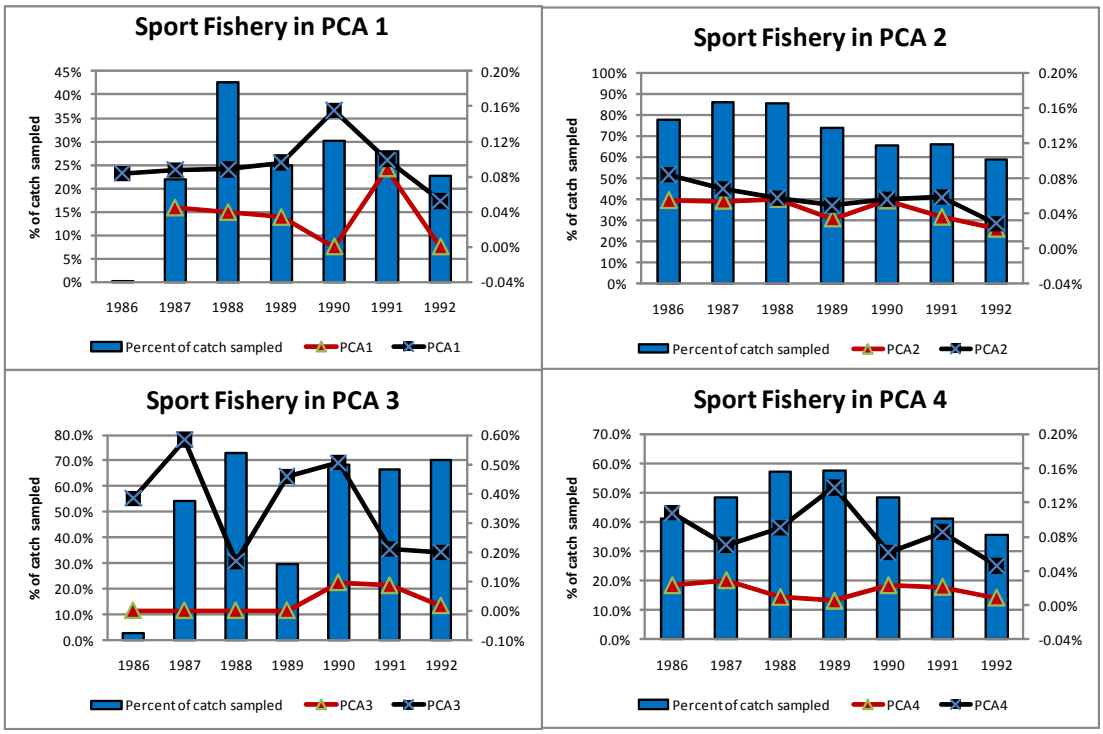

Figure 9. Comparison of tag recovery rates between sampled (triangles) and landed catch (squares) by Punch Card Area (PCA) and year.

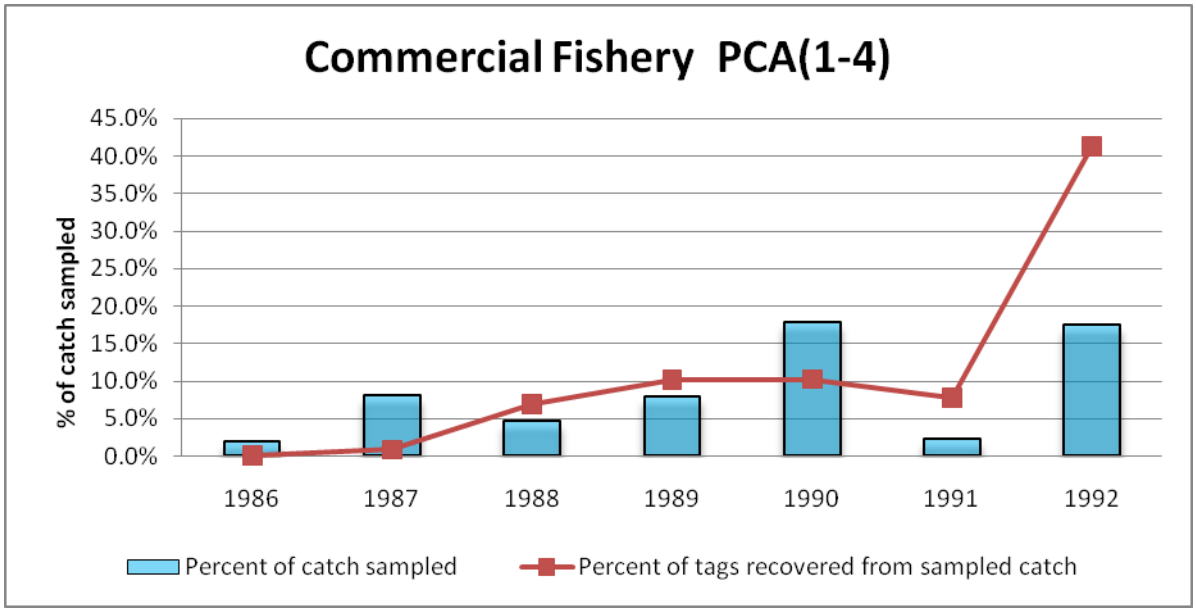

Figure 10. Comparison of percent of sampled catch by year and percent of total tags recovered from the commercial fishery.

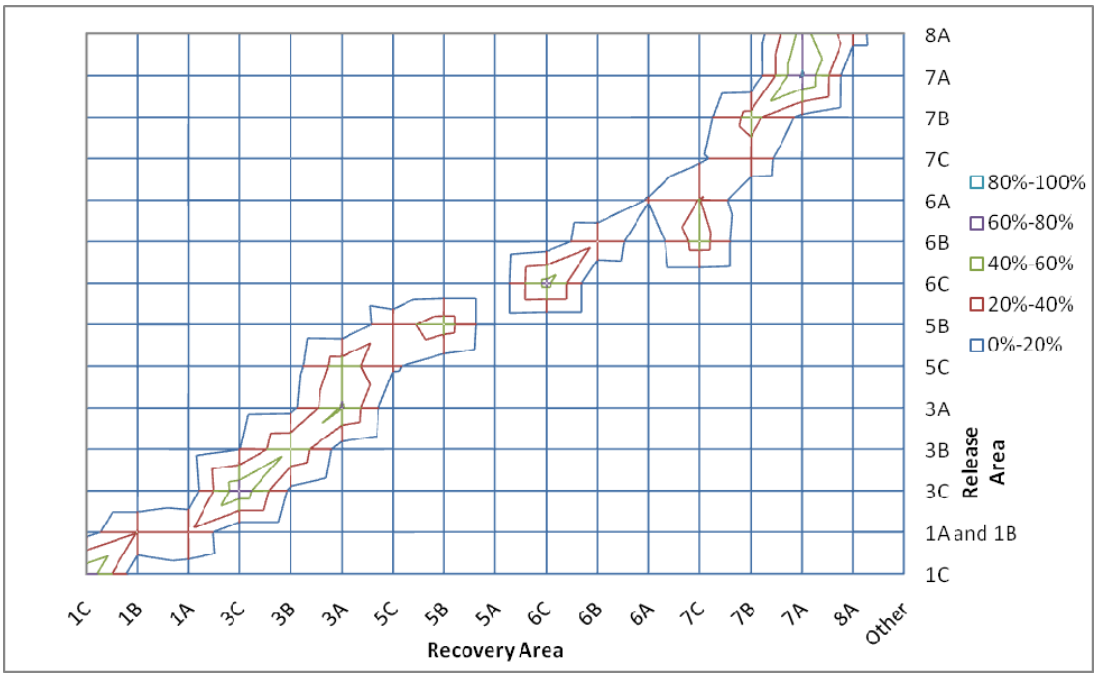

Figure 11. Surface area diagram of the percent of tags recovered by release and recovery area.

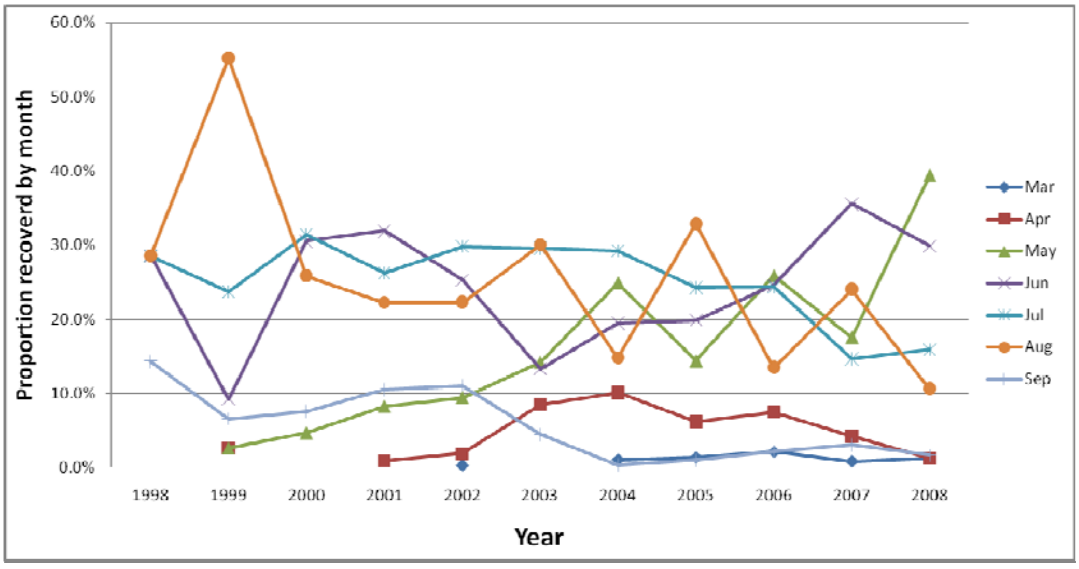

Figure 12. Proportion of tags (# of tags/total annual tag recovery) by month and year.

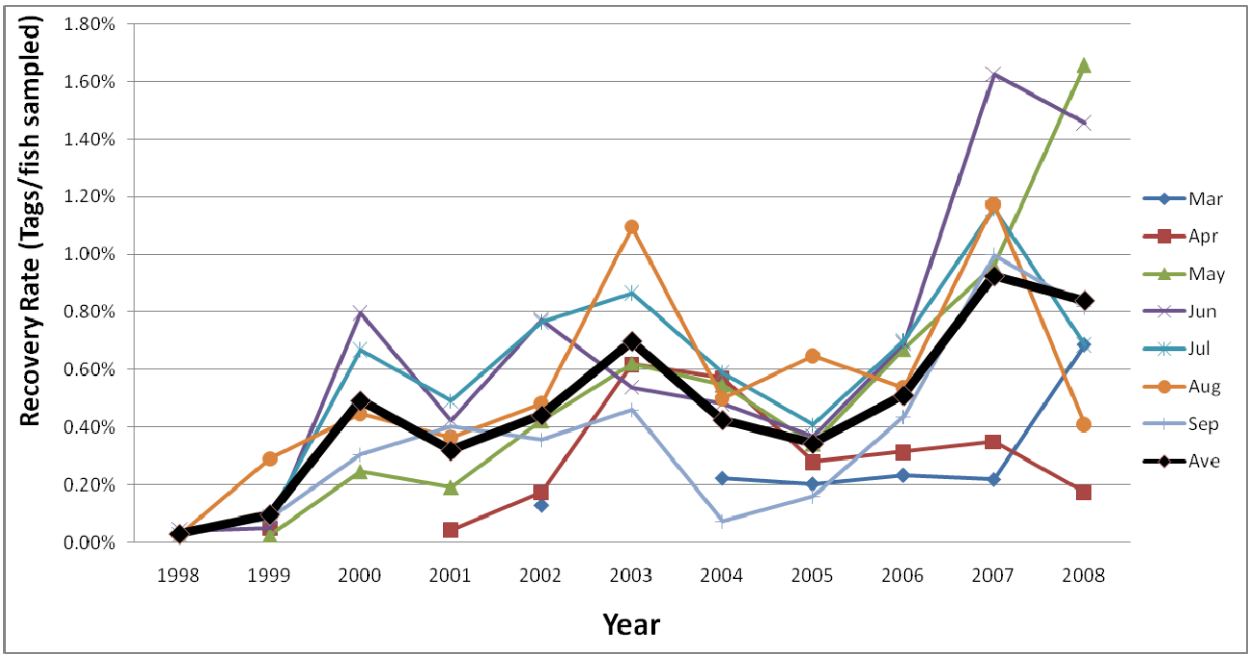

Figure 13. Monthly tag recovery rate (# of tags/# of sampled fish) by month and year.

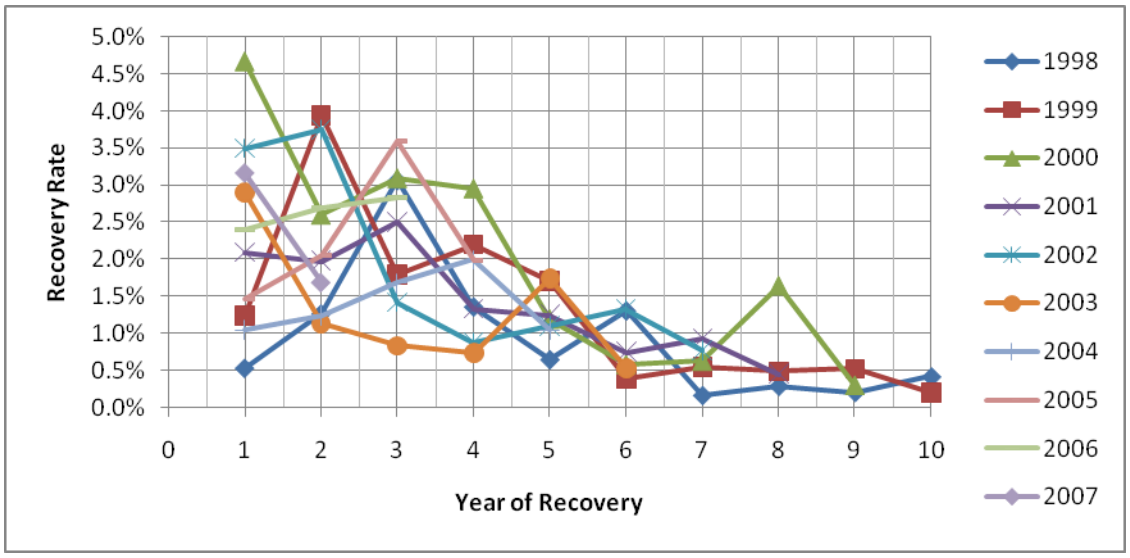

Figure 14. Recovery rate (# of tags recovered//# of tags released) by year of release and recovery year.

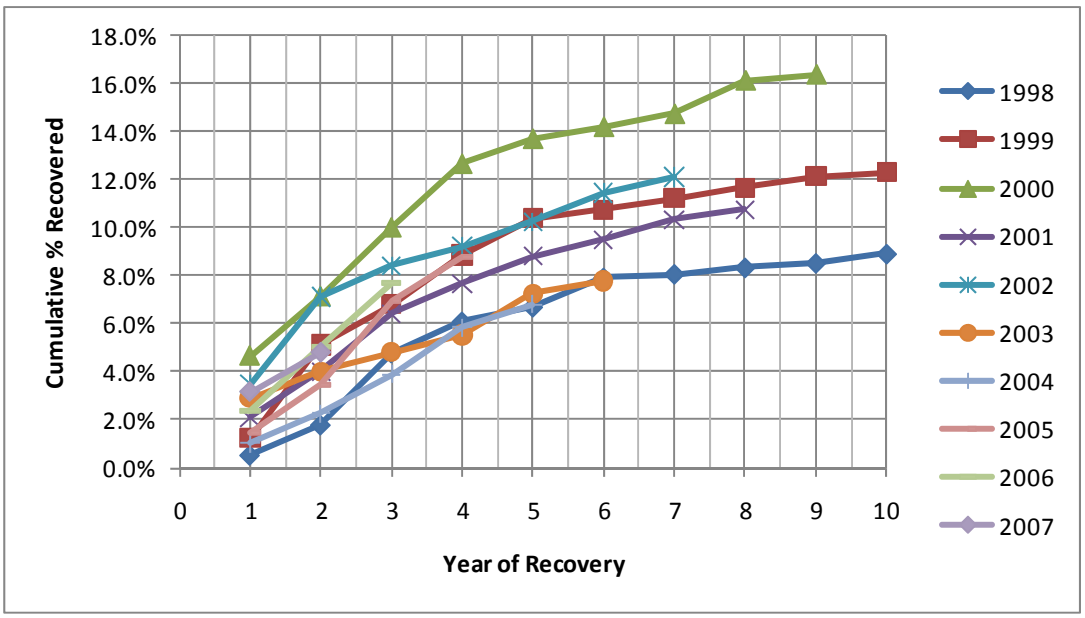

Figure 15. Cumulative percent of tags recovered (total tags recovered//# of tags released) by year of release and recovery year. The 0-1 interval represents the first year at large.

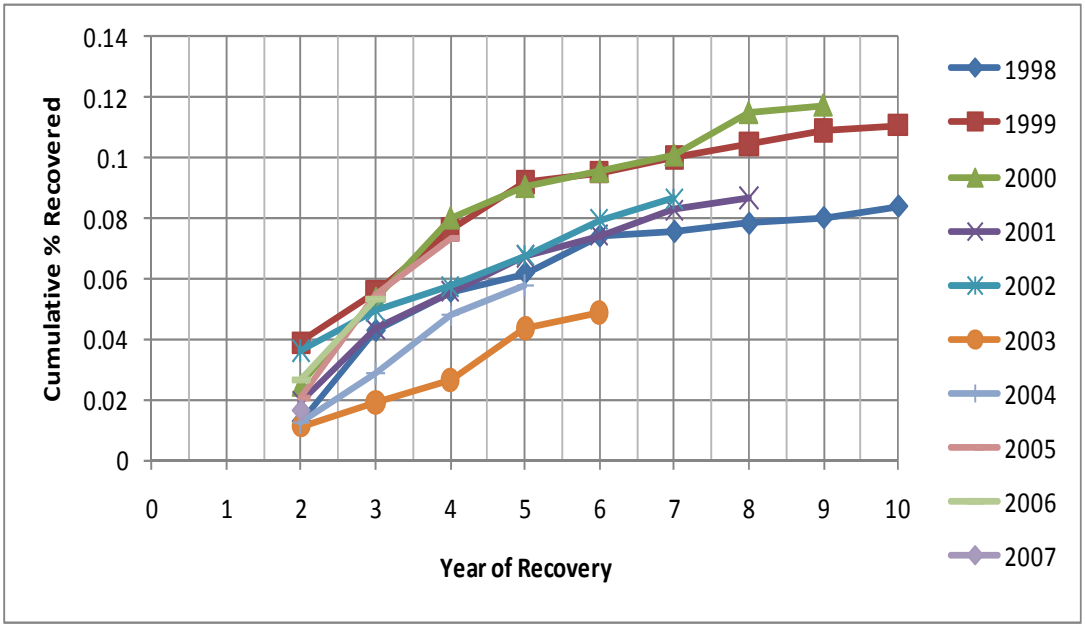

Figure 16. Cumulative percent of tags recovered (total tags recovered//# of tags released) after first year of release by year of release and recovery year. The 1-2 interval represents the end of the second year at large.

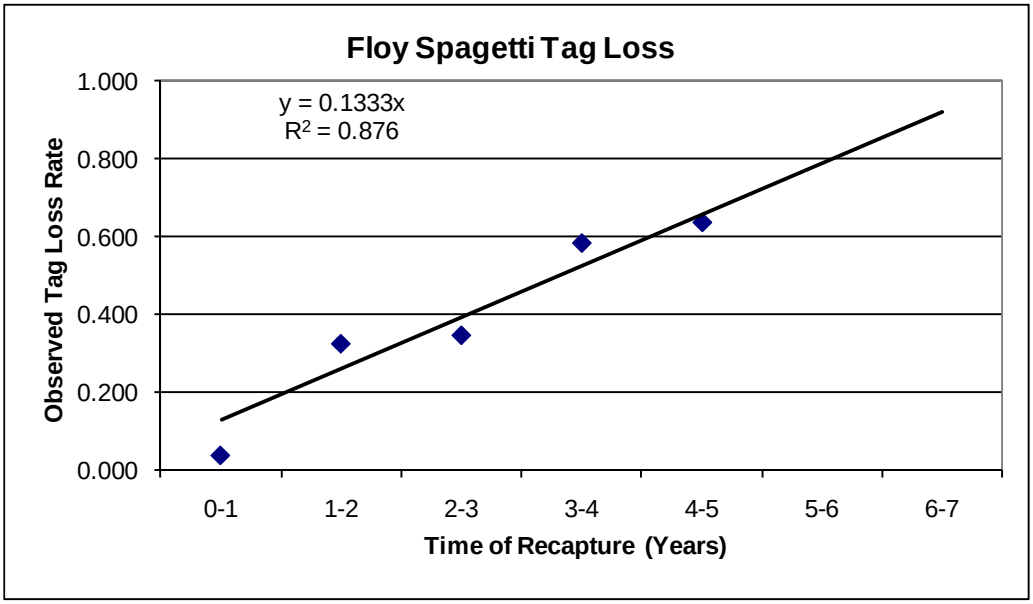

Figure 17. Observed and estimated tag loss rate for black rockfish tagged with Floy spaghetti tags.

Figure 18. Example of biotic growth on Floy spaghetti tag recovered from black rockfish that was at large for four years.

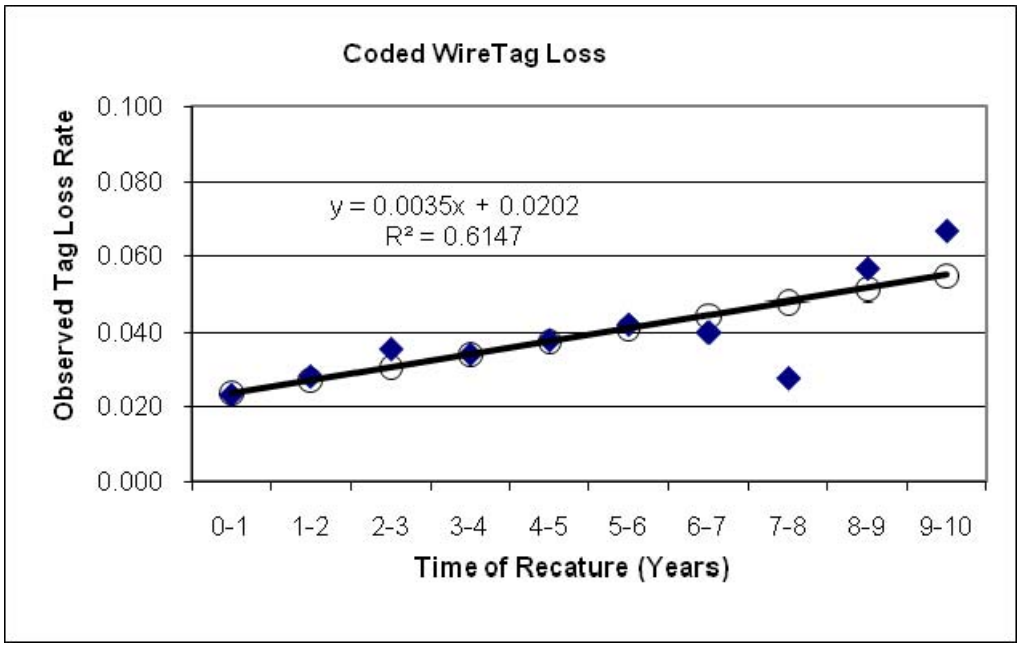

Figure 19. Observed and estimated tag loss rate for black rockfish tagged with CWT.

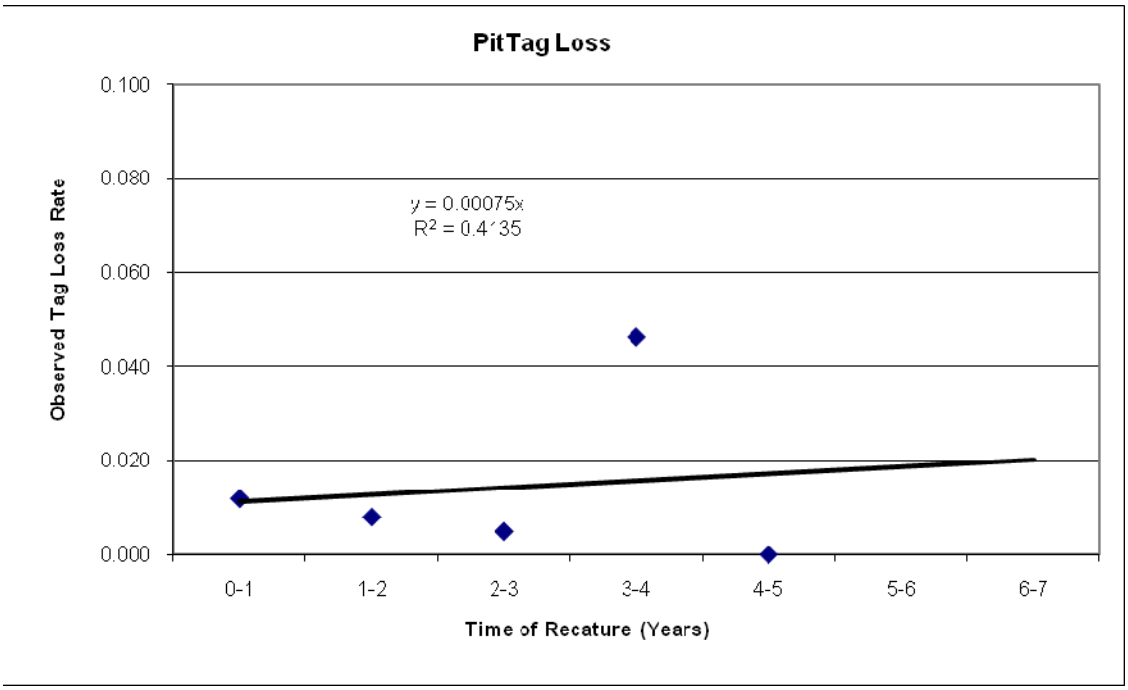

Figure 20. Observed and estimated tag loss rate for black rockfish tagged with PIT.

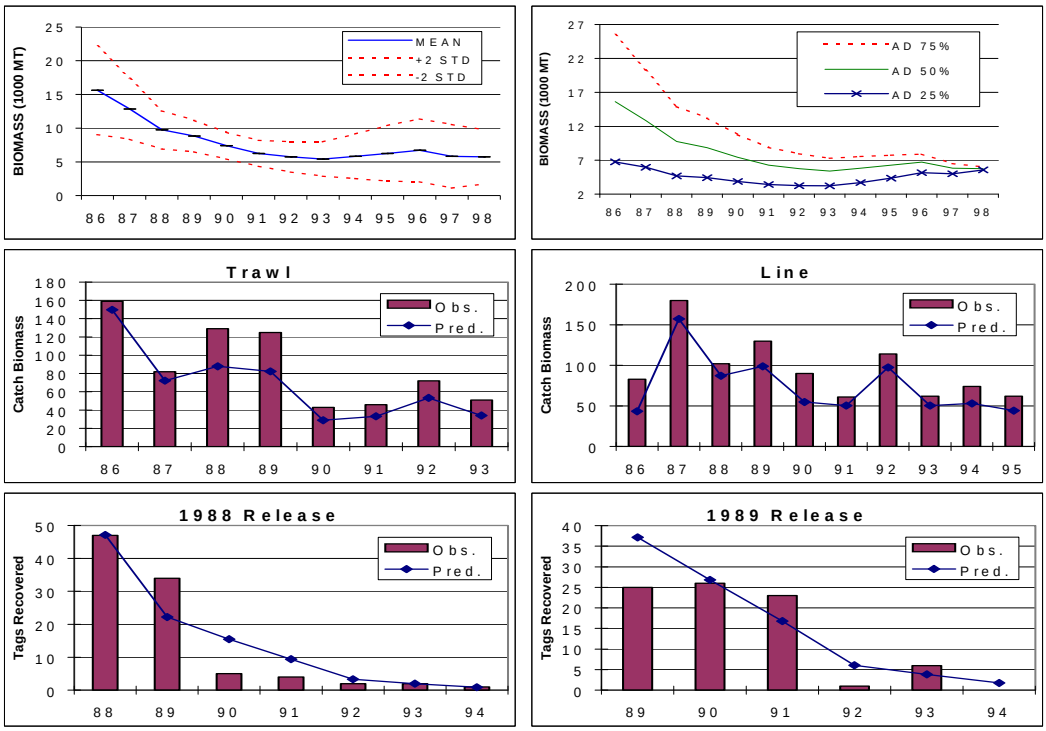

Figure 21. Estimated stock biomass trend based on a 25%, 50% and 75% tag-reporting rate and fit to tagging data.

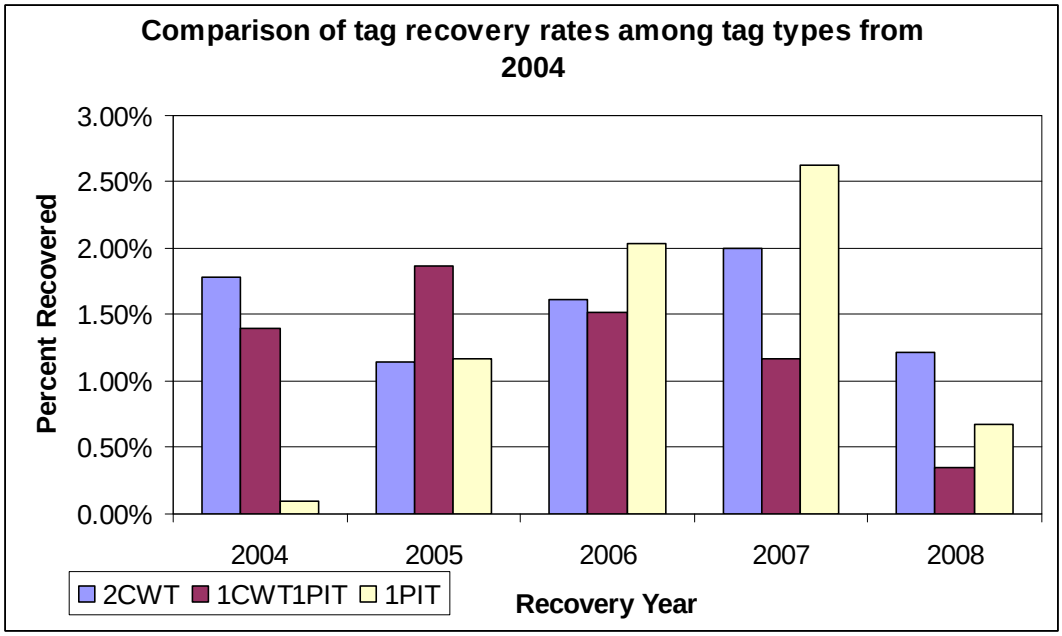

Figure 22. Comparison of the percent recovery among tag groups released in 2004.

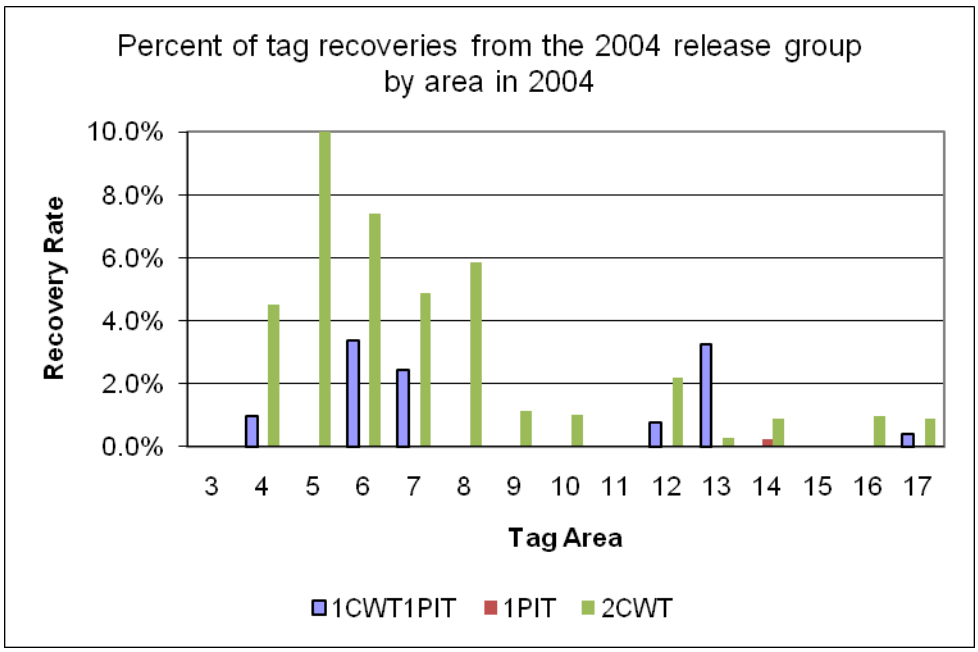

Figure 23. Comparison of 2004 CWT tag recovery rates by release area.

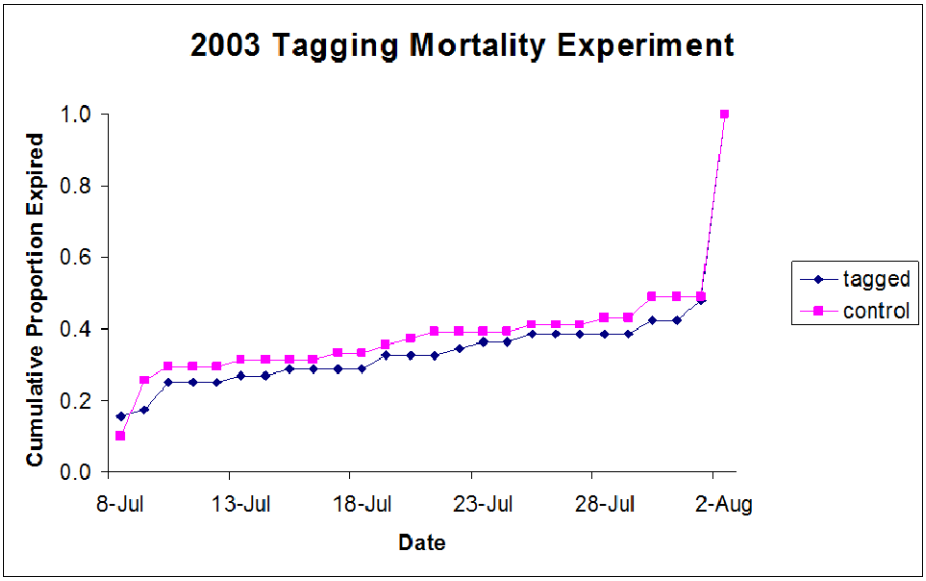

Figure 24. Comparison of the cumulative proportion of fish that died in a control group (51 individual fish that were not tagged) compared to a tagged group of fish (53) that were held in aquarium in 2003. Note that on August 2nd all fish died due to failure of aquarium to maintain adequate oxygen levels.

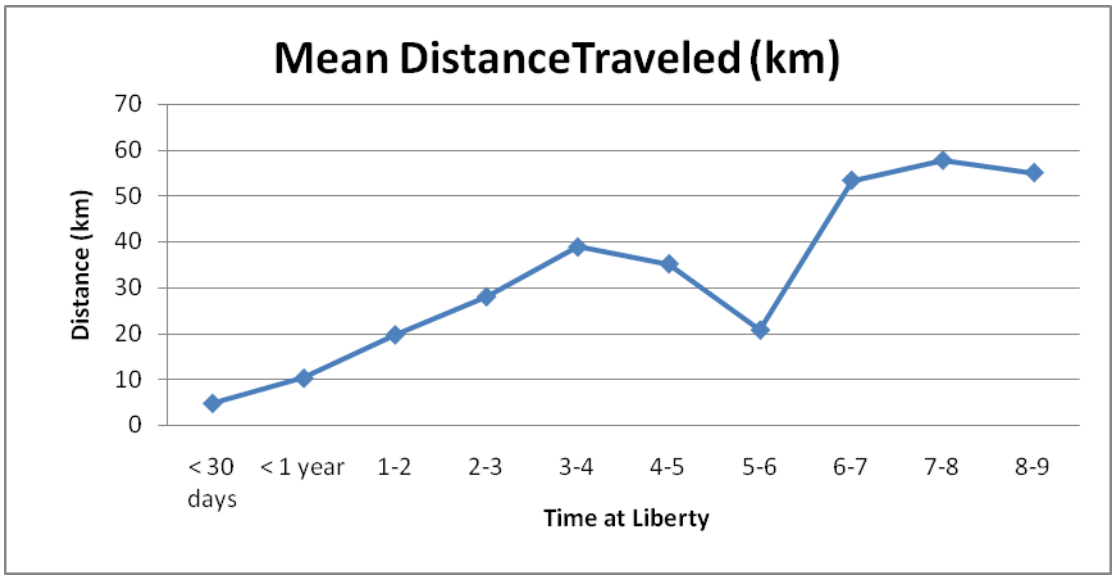

Figure 25. Comparison of mean distance traveled and time at liberty.

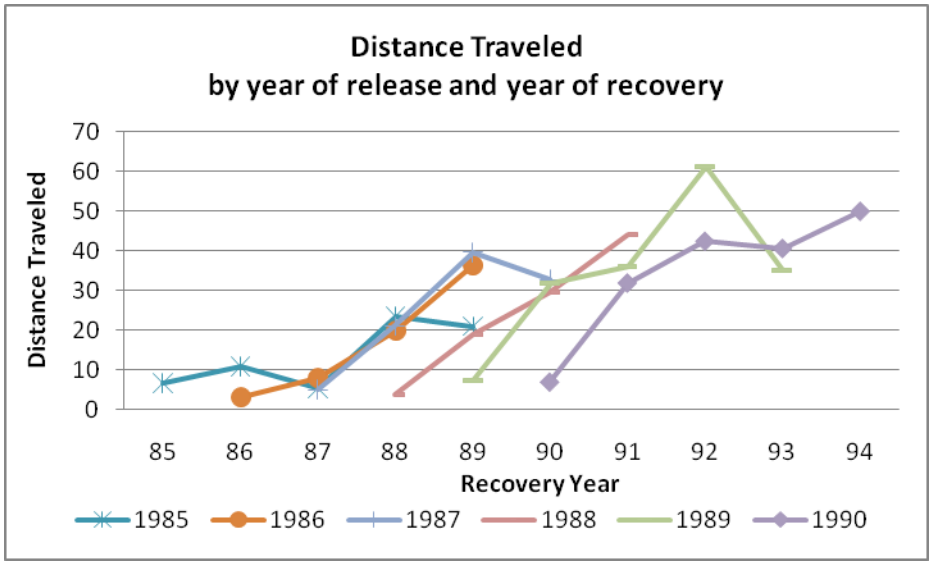

Figure 26. Comparison of mean distance traveled by year of release and year of recovery.

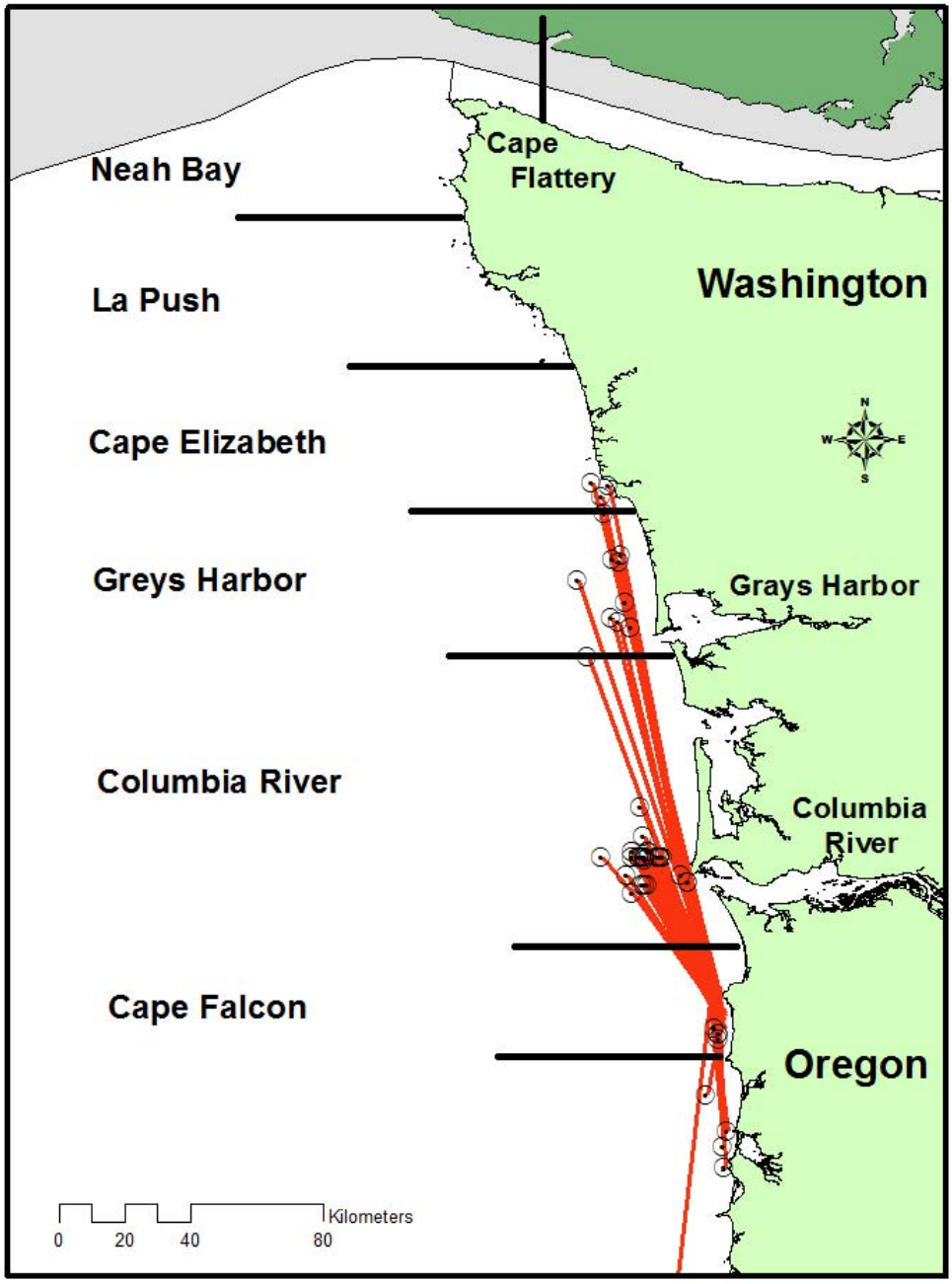

Figure 27. Observed movement of Cape Falcon releases for all years.

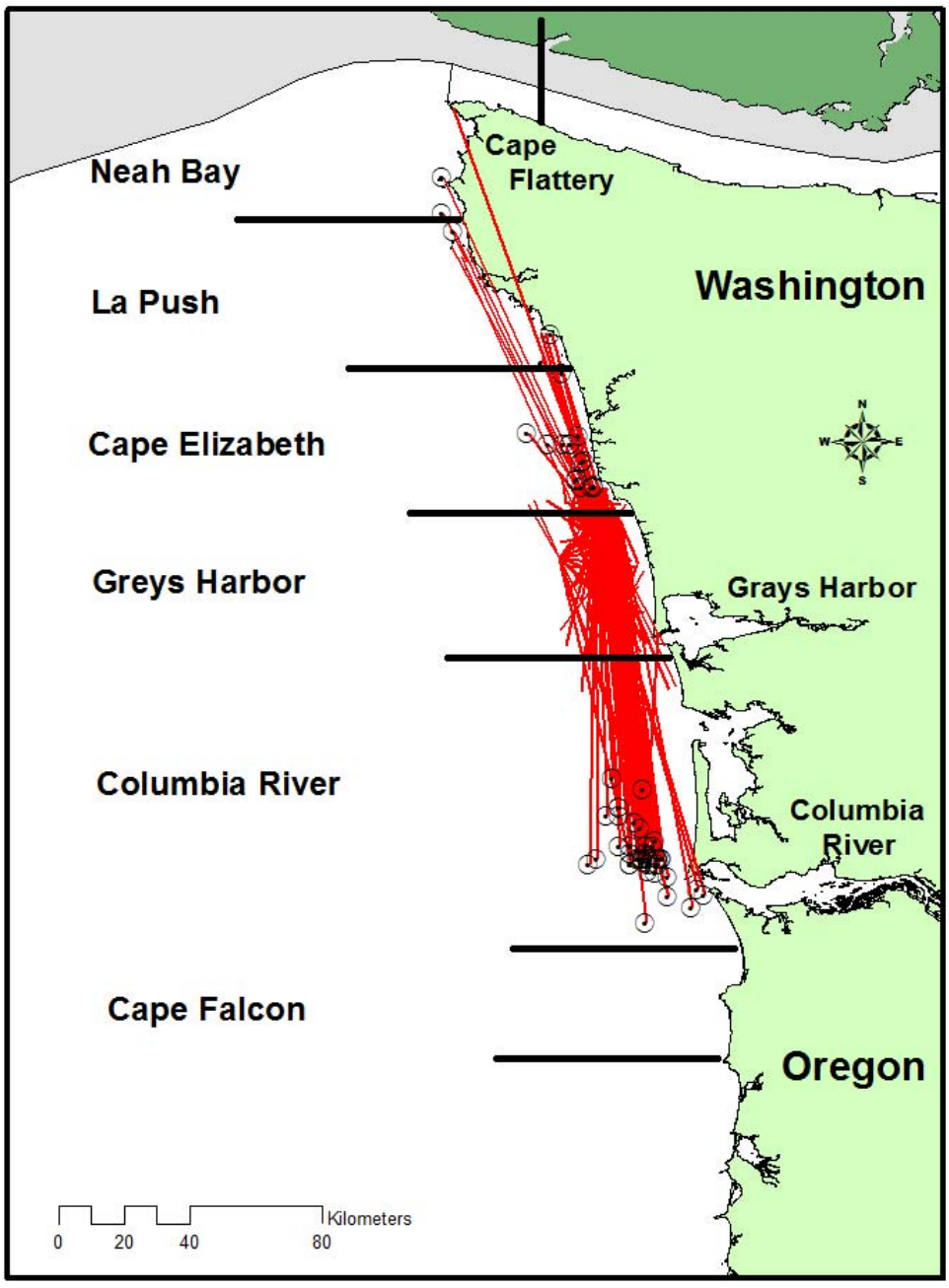

Figure 28. Observed movement of Grays Harbor releases for all years.

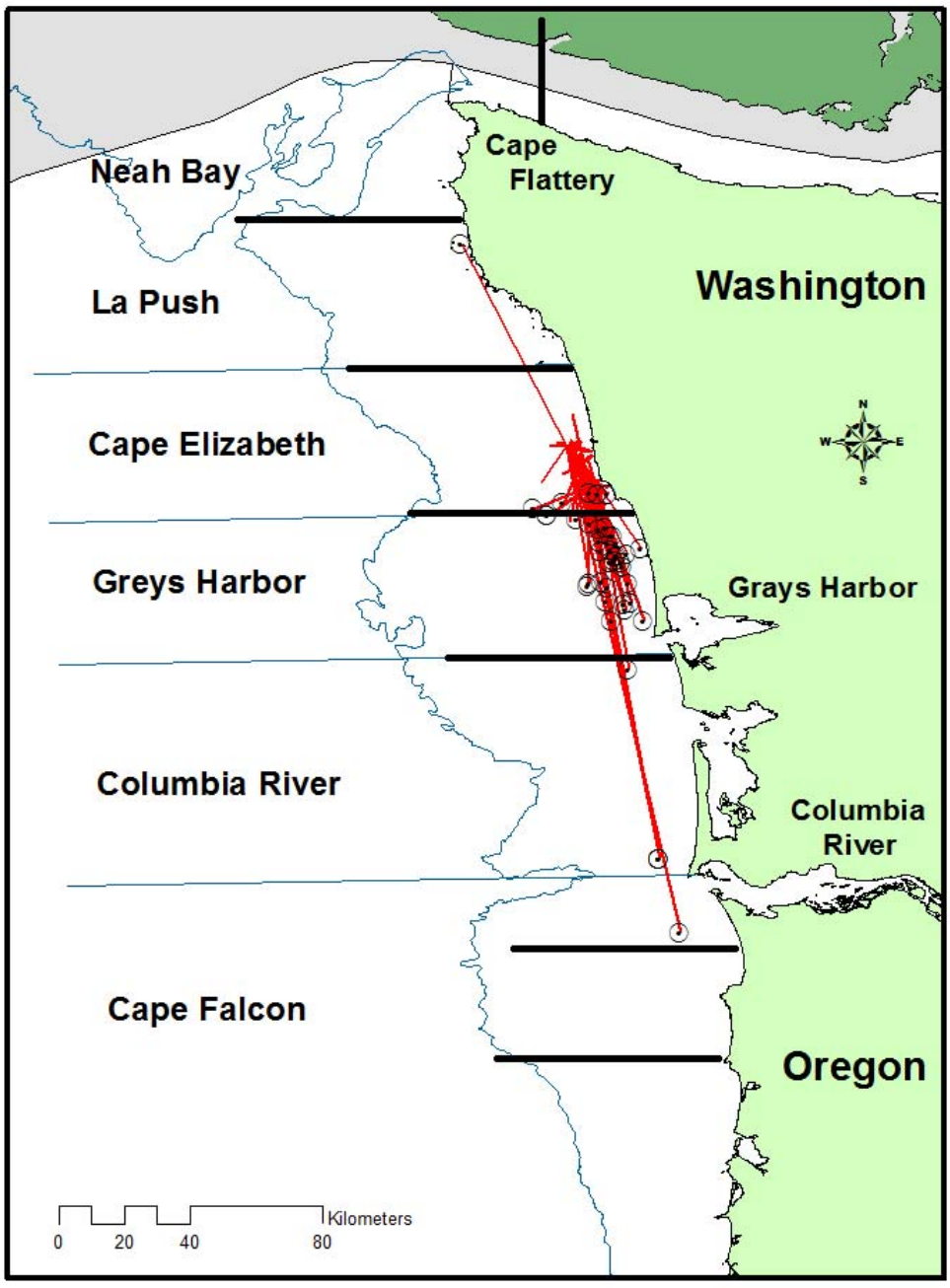

Figure 29. Observed movement of Cape Elizabeth releases for all years.

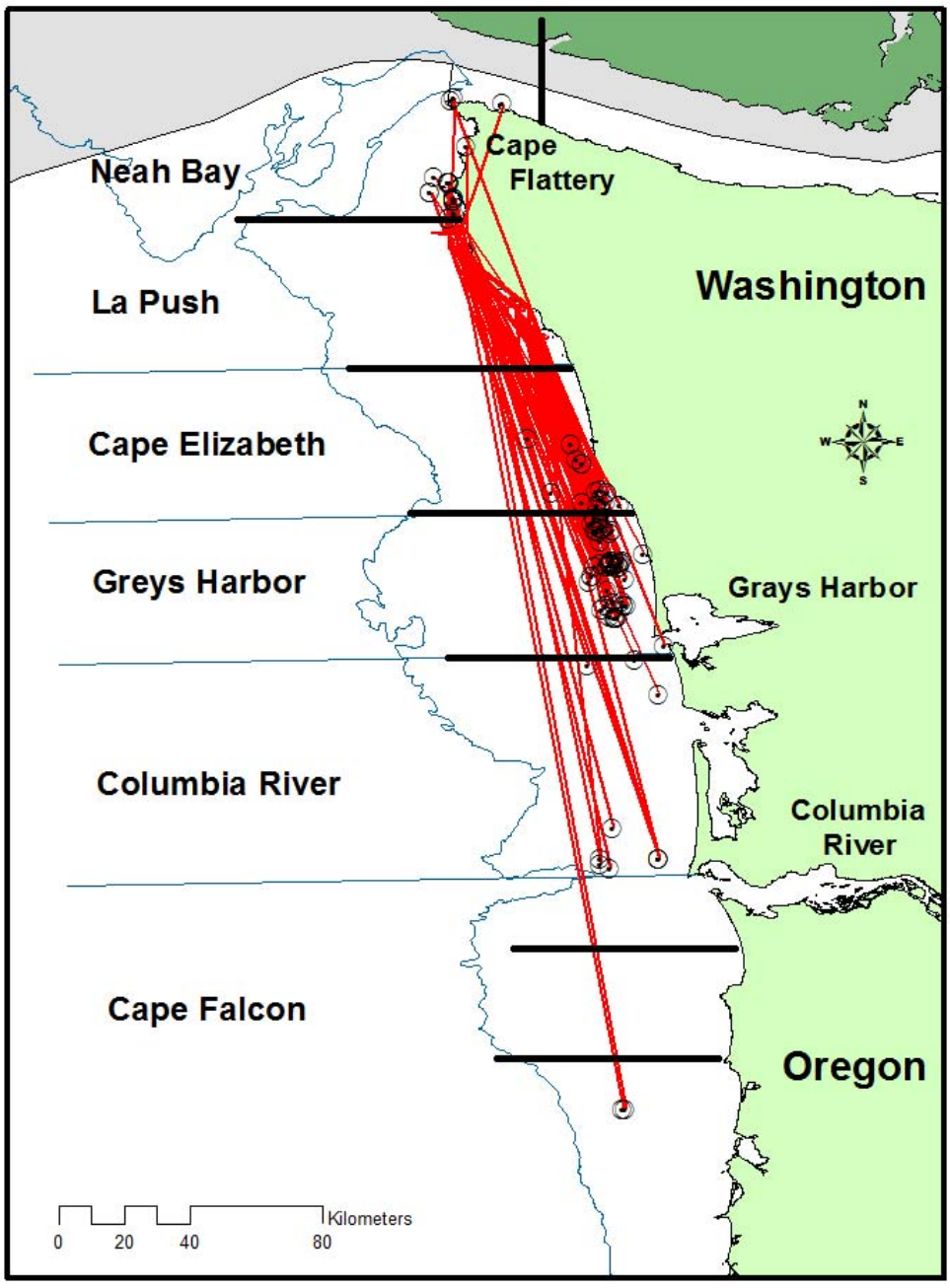

Figure 30. Observed movement of La Push releases for all years.

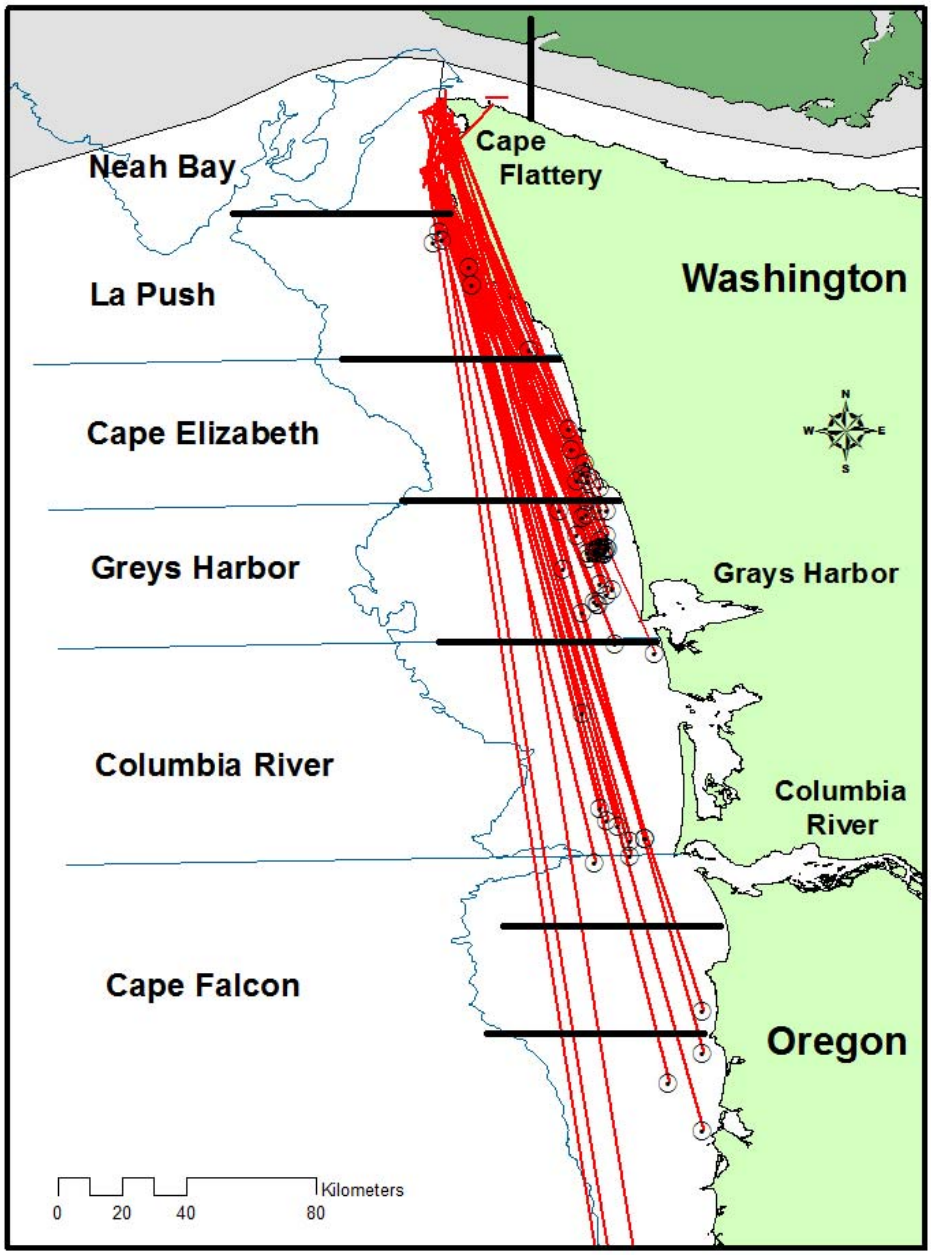

Figure 31. Observed movement of Neah Bay releases for all years.

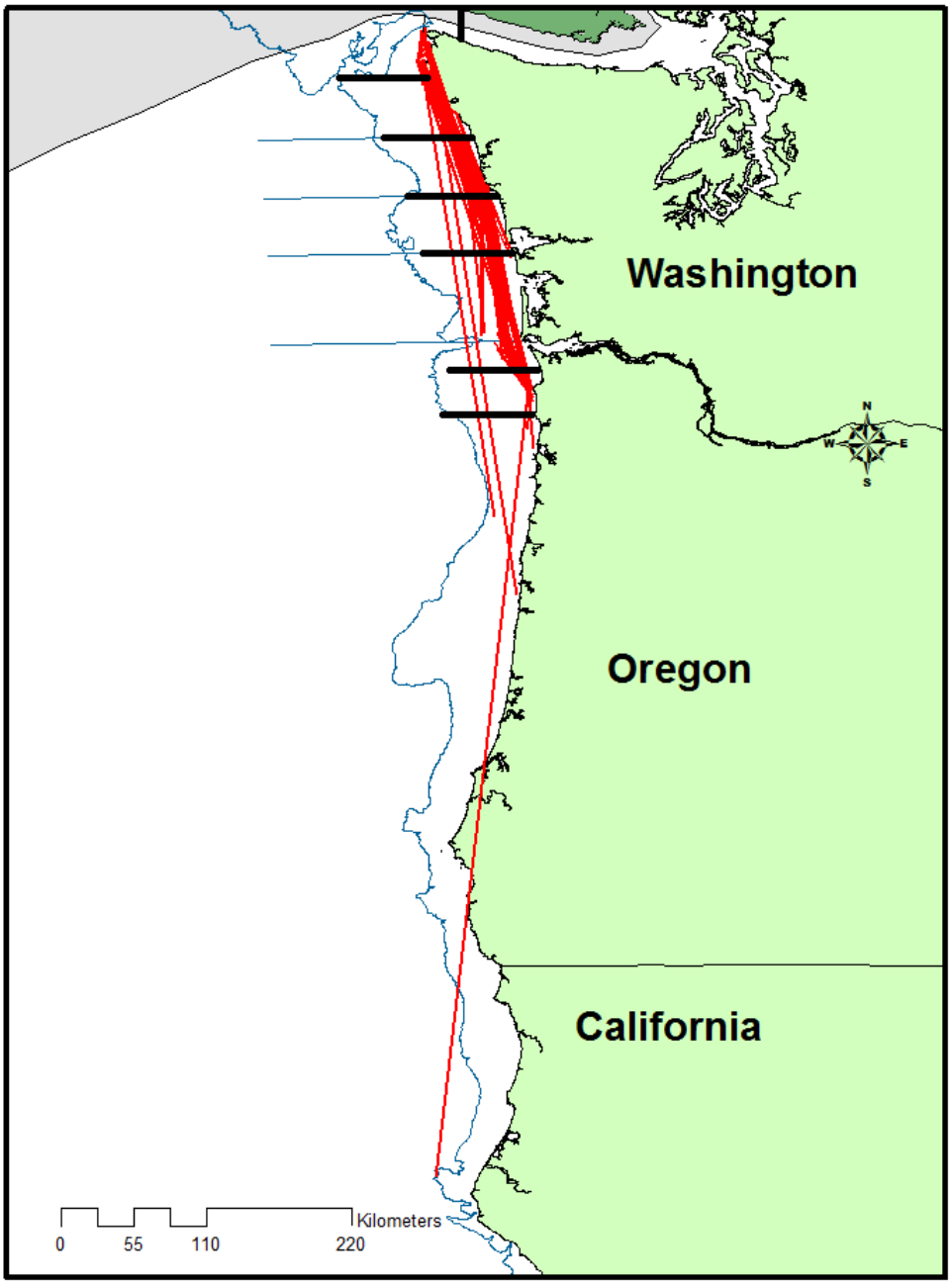

Figure 32. Observed movement of fish travelling more than 150 kilometers.

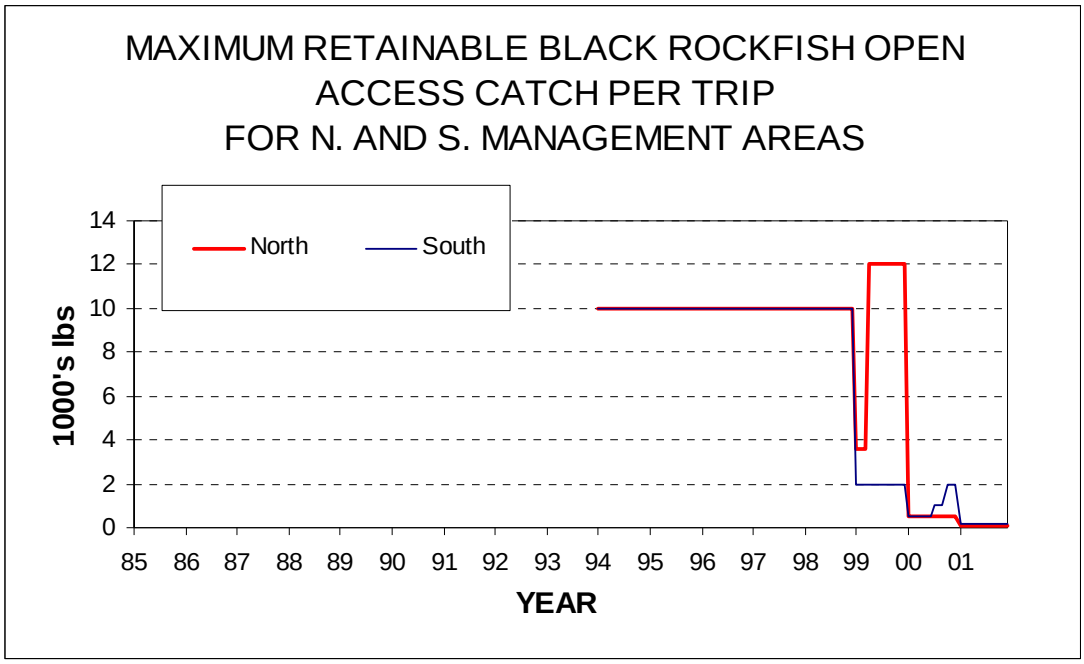

Figure 33. Regulatory changes in the open access commercial fishery between 1994 and 2001.

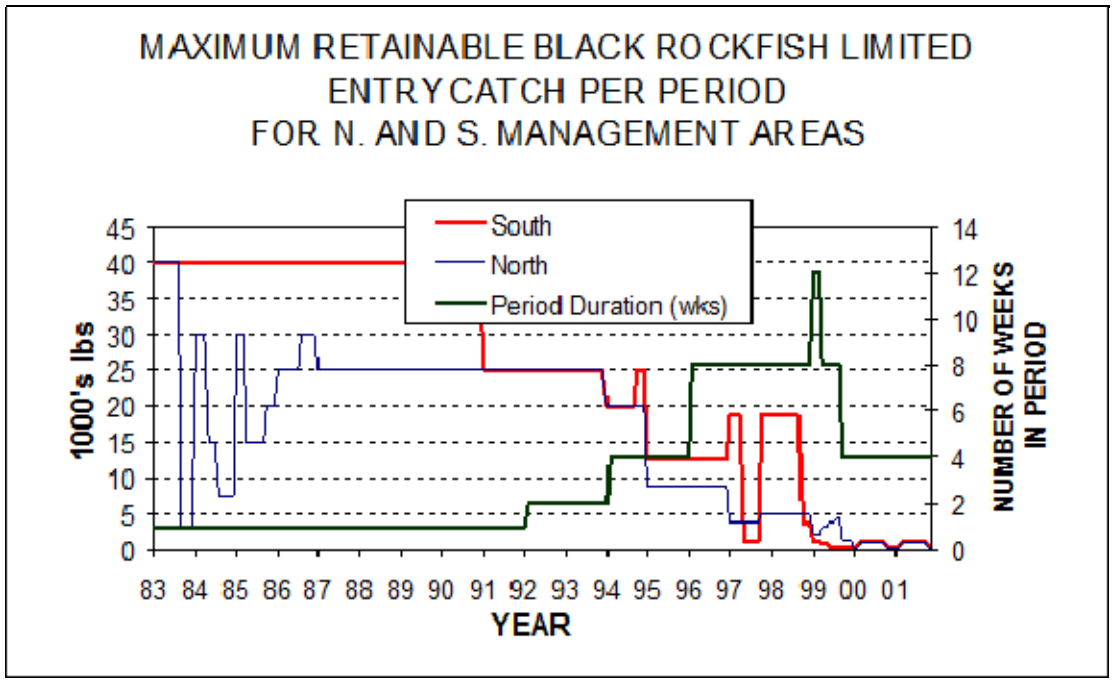

Figure 34. Regulatory changes in the limited entry fishery between 1985 and 2001.

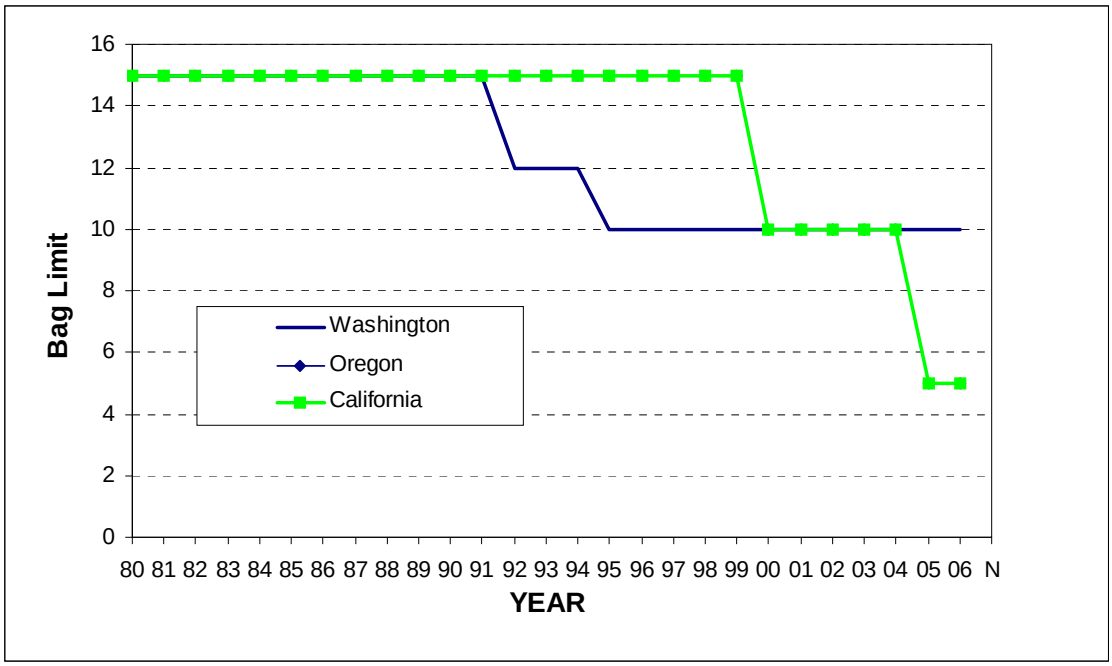

Figure 35. Regulatory changes in the sport fishery by State between 1985 and 2001.

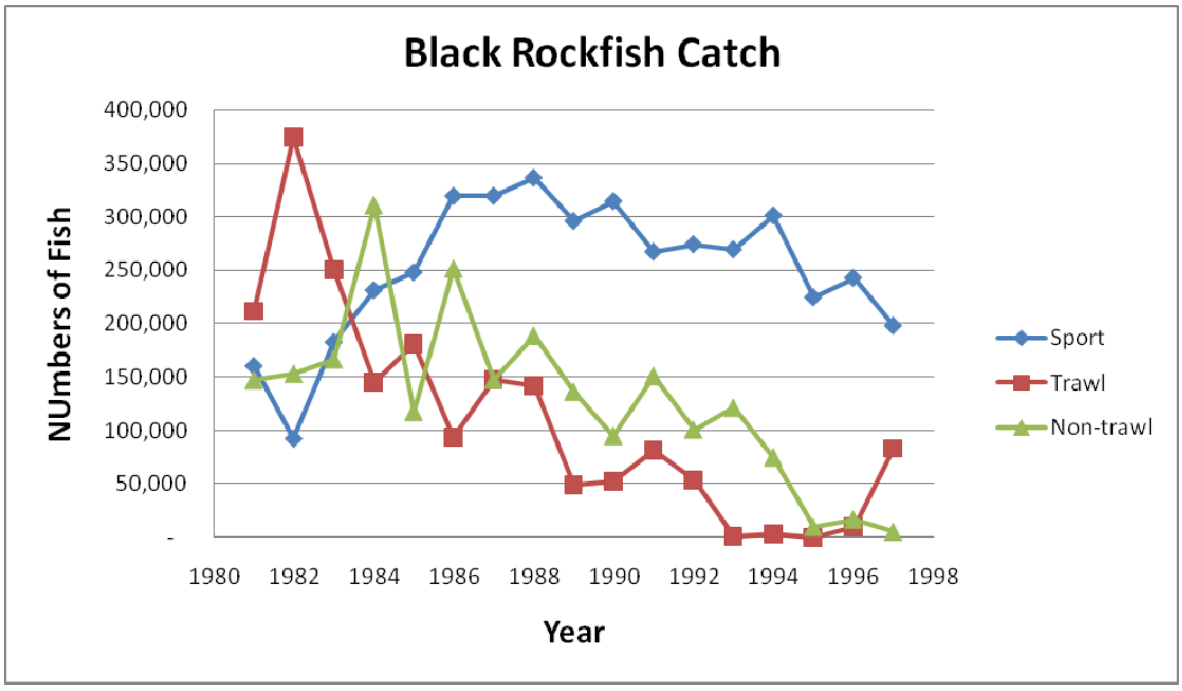

Figure 36. Black rockfish catch by fishery between 1980 and 1998.

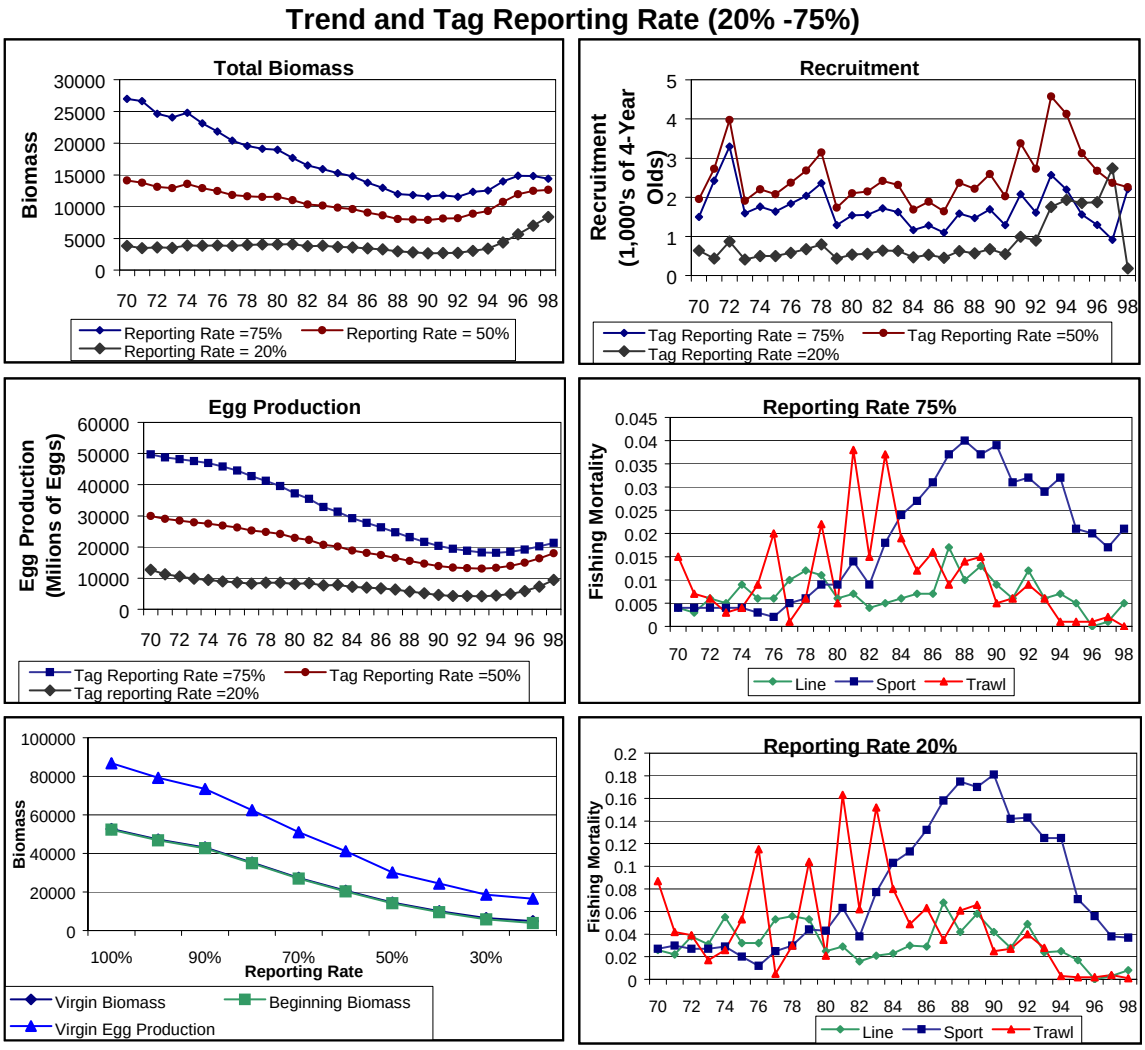

Figure 37. Results from the 1999 stock assessment (Wallace et al., 1999) showing model sensitivity to assumptions on non-reporting.

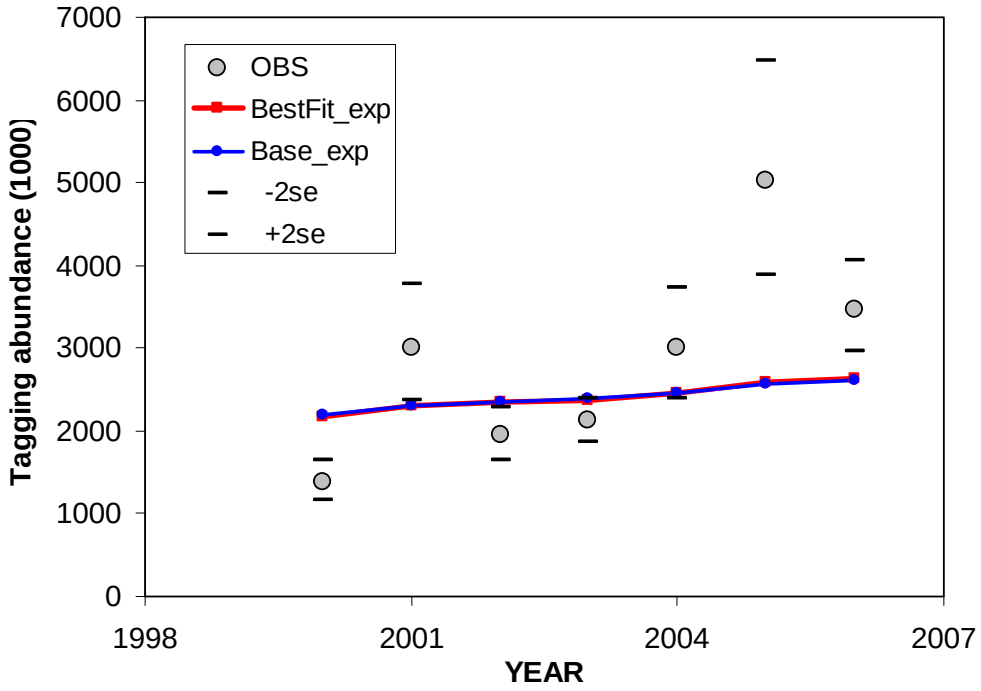

Figure 38. Results from the 2007 stock assessment (Wallace et al., 2007) showing model fit to estimates of abundance derived from Peterson estimates between 1998 and 2006.

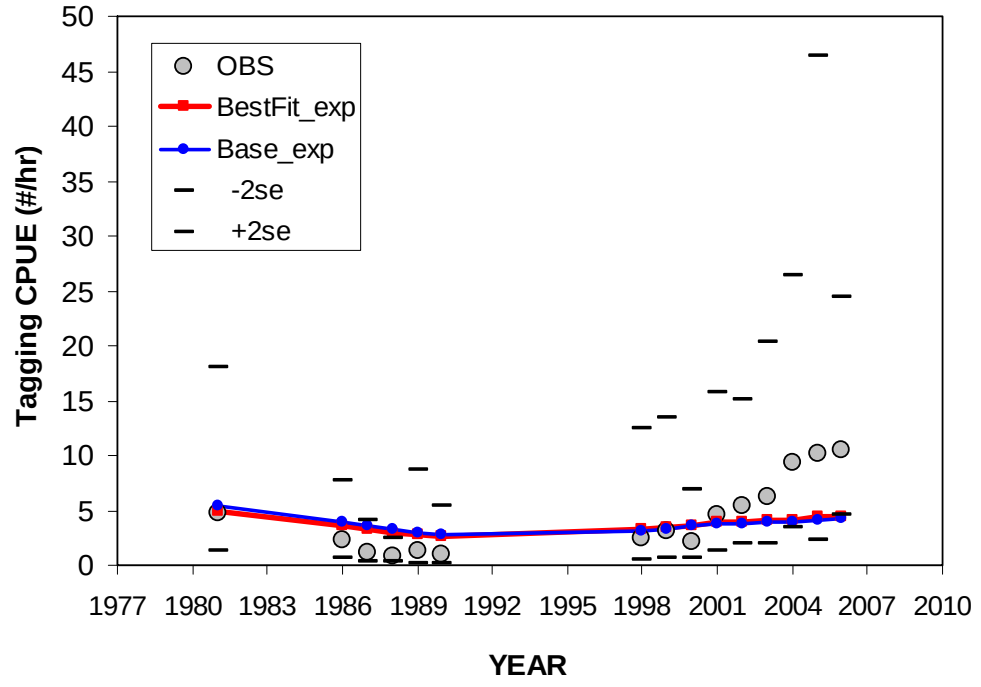

Figure 39. Results from the 2007 stock assessment (Wallace et al., 2007) showing model fit to tagging CPUE between 1998 and 2006.

Appendix A