NOAA Technical Memorandum NMFS-AFSC-320
doi:10.7289/V5/TM-AFSC-320

Feasibility of Tagging Sablefish, *Anoplopoma fimbria*, with Pop-off Satellite Tags in the Northeast Pacific Ocean

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center

April 2016

NOAA Technical Memorandum NMFS

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This document should be cited as follows:

Echave, K. B. 2016. Feasibility of tagging sablefish, *Anoplopoma fimbria*, with pop-off satellite tags in the northeast Pacific Ocean. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-320, 38 p. doi:10.7289/V5/TM-AFSC-320.

Document available: http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-320.pdf

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Feasibility of Tagging Sablefish, *Anoplopoma fimbria*, with Pop-off Satellite Tags in the Northeast Pacific Ocean

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April 2016

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ABSTRACT

Recent advances in satellite tagging technologies have provided scientists more opportunities to study movement and behavior of fishes independent of tag recovery. Until recently, this type of tagging was limited to large pelagic fish, sharks, and whales. Miniaturization of computer technology and improved batteries has allowed smaller tags to be developed, thus allowing for tagging of smaller-sized fish species. In addition, the use of magnetic field readings to estimate geolocations has introduced the ability to track deep-dwelling, high-latitude species that cannot use light for location estimates. A high-latitude demersal fish known for extensive movement throughout its life history is the commercially valuable sablefish, *Anoplopoma fimbria*. This species has been tagged using fishery-dependent anchor and archival tags, but due to the large size of satellite tags, fishery-independent tagging methods have not been used. Thus, studies of daily or seasonal movement, and critical life history movements such as towards spawning habitats, have not been possible. This paper discusses the feasibility, methods, and initial results of satellite-tagging sablefish in Alaska.

CONTENTS

INTRODUCTION

Generally, questions regarding movement are answered through tagging studies. Since the beginning of the 19th century, several marine species have been tagged using a variety of methods to examine the spatial distribution of the species, determine migratory patterns, and examine growth (e.g., Atkins 1885, Beaverton and Holt 1957). Sablefish, *Anoplopoma fimbria*, are a long-lived, highly mobile deep-dwelling species that inhabit the northeastern Pacific Ocean from Baja Mexico to the Gulf of Alaska (GOA), westward to the Aleutian Islands (AI), and into the Bering Sea (BS; Hanselman et al. 2013). They are one of the deepest dwelling commercially valuable species, with an ex-vessel value of over $100 million annually. It is currently unknown if there is directed movement to spawning locations or if there are spawning aggregations for sablefish in Alaska. While sablefish have been tagged with fishery-dependent tags in Alaska since 1972, sablefish spawn during the winter months when there is no directed fishing and hence no tag recoveries. Knowledge of spawning and nursery locations could allow for identification of specific areas or habitats that are important for the species' recruitment, survival, and growth. The primary purpose of this study was to determine if new tagging technology could be applied to this species, which could ultimately be used to answer questions regarding sablefish movement towards spawning locations.

Spatial distribution and movement of sablefish have been studied for over 40 years by the Alaska Fisheries Science Center (AFSC) in the northeast Pacific Ocean by using both traditional external anchor tags (Floy) and internal electronic archival tags (Lotek). Since 1972, over 360,000 sablefish have been tagged with traditional anchor tags, of which nearly 34,000 have been recovered (Echave et al. 2013). Upon release and recapture of the fish, geoposition (i.e., recapture location) and biological data (e.g., sex and length) may be collected; however, information is limited to release and recapture locations, and inference about daily movements and the behavior of the fish while at liberty is limited. Beginning in 1998, electronic archival tags have been placed inside juvenile and adult sablefish. In that time, approximately 1,460 archival tags have been released, of which 141 have been recovered. Upon release and recapture of an archival-tagged fish, geo-position (i.e., recapture location), archived depth, temperature, salinity, and biological data may be collected. The use of electronic tags has provided an in-depth look at the vertical and horizontal movement of the fish, in addition to changes in the fish behavior in

regards to the surrounding environmental conditions (temperature and depth). The analysis of data collected by archival tags after recovery has improved the understanding of the migration of juvenile sablefish onto the slope as well as recruitment into the fishery, and has provided insight into the behavior of adult sablefish during spawning.

While these two types of tagging methods have provided AFSC scientists with invaluable data regarding sablefish migratory patterns, movement rates, and growth, there are several limitations with this type of tagging. The primary limitation is that the recovery of data is dependent upon recovery of the tags in the fishery, and sablefish spawn in the late winter when there is no directed fishery for sablefish. Pop-off satellite tags (PSATs) are fishery-independent tags and have been used to study behavior of marine mammals and fish for decades. PSATs are similar to electronic archival tags in that they collect depth and temperature data at predetermined sampling intervals, but they also record an estimated geo-location. PSATs release from the fish at a preprogrammed date and transmit archived data to passing satellites.

The original PSATs were large tags, with a buoyant float, and were only capable of recording data such as temperature and depth. While PSATs have been used on a number of fish species within the last 20 years (Atlantic bluefin tuna, *Thunnus thynnus, (*Block et al. 1998)*;* swordfish, *Xiphias gladius* (Dewar et al. 2011); striped marlin, *Kajikia audax* (Domeier et al. 2006)*;* blue shark, *Prionace glauca* (Musyl et al. 2011a); shortfin mako, *Isurus oxyrinchus* (Musyl et al. 2011b); silky shark, *Carcharhinus falciformis* (Musyl et al. 2011b); oceanic whitetip shark, *C . longimanus* (Musyl et al. 2011b); and bigeye thresher, *Alopias superciliosus,*(Musyl et al. 2011b)), the majority of tagged species have been pelagic and substantially larger in size. Geo-location using light levels developed in the early 2000s, but it has limitations for deep-dwelling species and high latitudes. Recent advances in PSAT technologies have created smaller tags, allowing for deployment on a wider range of fish species, as well as including magnetic field based geolocation which does not have global limitations and is not impacted by factors such as turbidity. These advances in tag technology may provide tags usable for sablefish, which is too small for the traditional PSAT and is a deep-dwelling, high-latitude species.

When planning any tagging study, it is important that there be an assessment of the objectives that are to be met in relation to the cost/benefit of the project. This assessment should also include the number of fish that need to be tagged considering the number of recoveries

expected and needed for statistical analyses planned for the data and the risk of mortality due to the tagging methodology, the handling time of the fish, and the experience of the personnel used for the study. Because this was the first use of external satellite tags on sablefish, the first step needed for this study was to design and practice, in a laboratory setting, the attachment method that would cause the least harm to the fish and stay implanted.

Most tagging experiments are based on the assumption that the behavior, growth, and survival of the tagged fish is similar to that of an untagged fish, and consideration of the technique of implantation or attachment of the tag to the fish will have an impact on these assumptions. Studies in the laboratory may not provide accurate assessments of changes in behavior due to tagging because the laboratory setting likely causes fish to change their behavior. Regardless, because of the invasive nature of the proposed tagging, the possibility of both behavioral and physiology disruptions, the large cost of the tags and the platform for releasing them, and the absence of information on tagging sablefish with PSATs, laboratory studies were necessary to choose a tagging method that would minimize mortality and behavioral changes.

This paper addresses the first objective of our larger study to determine if sablefish in Alaska practice migrations for spawning purposes, and if spawning aggregations exist in Alaska, to then explore the feasibility of tagging sablefish with PSATs and to choose the best method for attaching the tags, considering their size, habitat, and minimized handling time. To accomplish this objective, we tagged sablefish in the laboratory using different attachment methods and monitored their health and behavior. The second objective of this study was to provide a detailed description of PSAT tagging methods for sablefish; this protocol could also be applied to tagging other deep-dwelling, high-latitude fish or similarly-sized fish.

MATERIALS

Description of Tags

Two tags from Desert Star Systems, LLC, were used in this study: the SeaTag-MOD PSAT (Fig. 1) and the SeaTag-GEO PSAT (Fig. 2). These tags were chosen based on three criteria: 1) cost, 2) ability to measure the strength of the earth's magnetic field for location estimation, and 3) size. The SeaTag-MODs were used in the first (2012) year of the study. These tags are 25 millimeters (mm) in diameter, 275 mm long, weigh 163 grams (g) in air, and are pressure rated to 2,000 meters (m). The SeaTag-GEO was created after the start of this project,

and it was used in the second (2013) and third (2014) years of the study. They are 14.6 mm in diameter, 178 mm long, weigh 41.7 g in air, and are pressure rated to 1,200 m. The SeaTag-GEO is smaller in size and weight than the SeaTag-MOD, but does not collect depth data and is pressure rated to a shallower depth. Both tag types are preprogrammed to release on a specified date, and once reaching the surface, archived data are uploaded to the ARGOS satellite network as received by polar orbiting satellites on successive passes. Both tag types will take daily measurements of depth, temperature, tilt on three axes, magnetic field on three axes, and light levels. In addition to end point (pop-off) location derived from Argos satellites, daily latitude estimates during time at liberty are determined using archived magnetic field values, and longitude estimates are determined by the local noon time.

Tag Attachment

There are many factors to take into account when choosing a method to externally attach tags: drag effect, handling time, potential for tag loss, minimizing the effect on the normal behavior of the fish, and the vulnerability to infections and wounds at the attachment point. Taking into account this long list of considerations, two tag attachment methods were employed to externally attach the PSAT to the fish, referred to from here on as Method 1 and Method 2. Method 1 was used in the first 2 years of tagging (2012 and 2013), and Method 2 was utilized in 2014 after seeing a high amount of what appeared to be early tag shedding.

In Method 1, we followed tether methodology used for tagging Pacific halibut, *Hippoglossus stenolepis* (Seitz et al. 2003), and style of darthead used on Atlantic bluefin tuna (Block et al. 2001), both described below. No matter the attachment method, it is important to remember that the tag should not chafe the back of the fish (this is caused by too long of a tether), and the tag cannot be too long so that the antenna interferes with the fish tail, which has been known to disrupt the behavior of the fish. Method 1 tag tethers (Fig. 3) were approximately 3 to 4 inches in length, constructed from 300 pound (lb) monofilament. A brand of monofilament that is resistant to stretch is preferred. The following are instructions for constructing the tag tethers used. Cut approximately 7 inches of monofilament line using heavy duty scissors at an angle so that the end of the line is not crushed. The cut end will be angled. String one end of the line through a stainless steel crimp sleeve (oval sleeves for 1/16 inch line), then through the eye of a stainless steel dart head (Fig. 4, Hallprint, 316L surgical grade stainless steel with sharpened

edge, 1 inch in length), and then again through the crimp sleeve. This will create a loop that attaches the monofilament line to the dart head. Minimize the excess line at the end of the loop. Make sure the crimp sleeve is centered on the monofilament line (i.e., the line is not angled in the crimp), crimp the sleeve directly against the long axis. Snip any excess line of the shorter end that was pulled through the eye of the darthead. Cut two, 3/4-inch pieces of marine grade heat shrink tubing (1/8-inch diameter). Slide one piece of shrink tubing over the crimped sleeve at the base of the tether near the dart head. This will be a snug fit. Slide the remaining piece of shrink tube as well as another stainless steel crimp sleeve loosely over the monofilament line. String the remaining free end of the monofilament through the eye at the base of the tag and then back through the remaining loose crimp sleeve. Pull enough monofilament line through the eye of the tag and crimp sleeve so that the overall length of the tag tether is between 3 and 4 inches. Once again, make sure the crimp sleeve is centered on the monofilament line and then crimped directly against the long axis. Cut excess monofilament. Slide the remaining loose piece of shrink tubing over this crimp sleeve; once again it will be a snug fit. Using a heat gun, shrink wrap the two pieces of shrink tubing, being careful not to overheat it. If the monofilament line turns transparent/opaque, it must be removed and redone.

Tether construction in Method 2 essentially followed the harness method used for tagging Atlantic salmon, with one insertion site instead of four (Lacroix 2013). Method 2 tag tethers (Fig. 5) consist simply of a piece of 250 lb monofilament (a brand resistant to stretch) approximately 12 inches in length with one end strung through the eye of the tag and crimped closed with an aluminum crimp sleeve (as in Method 1), and one extra aluminum crimp sleeve (size G) to close when tagging. The rest of the assembly occurs when attaching the tag to the fish, and is discussed below in the *Tagging Method* section.

Tag Applicator

For Method 1, a tag applicator (Fig. 6), consisting of a wooden handle with a notched stainless steel dart inserter (Hallprint) screwed in at one end, is used to insert the tag into the fish. The wooden handle should be approximately 30.5 cm in length, of a comfortable diameter for the average person to be able to hold with one hand. It is better to have the diameter of the grip on the smaller side as the tagger will also need to be able to hold the tag with this hand as well. The stainless steel dart inserter should be approximately 12 cm in length.

For Method 2 tag attachment only a piercing needle is needed. The diameter should be large enough to accommodate the monofilament and long enough to pierce the entire girth of the fish below the dorsal fin. We used a hollow stainless steel loop tag applicator (Fig. 7, Hallprint).

METHODS

Tagging Method

Method 1

Take the measurement (fork length; FL) of the fish. If the fish is of the predetermined appropriate tagging size, proceed with tagging. Liberally apply Betadine solution to the dart head and tag tether. Have the tag applicator inserted into the darthead in an accessible spot for the tagger to easily grab with one hand. About an inch below the fourth dorsal fin ray, use a scalpel to make an incision (<1 inch) no larger than necessary to insert the dart head (better to be conservative). Make this incision slightly angled toward the posterior end of the fish (Fig. 8). Grab the tag applicator with your right hand, while stabilizing the fish with your left. Align the dart head into the incision. The dart head should be aiming toward the head of the fish, parallel to the dorsal fin. Steady the fish with your left hand. Hold the applicator at a forty-five degree angle and insert into the fish in a forward and downward direction until you feel and hear a “pop” (Fig. 9). This will actually take slight force. This means you have gone through and locked the darthead under the pterygiophores (fin ray bones, Fig. 10 a, b, c). After you feel as if you have gone completely through the pterygiophores, keep inserting the tag towards the head of the fish. Note that this is no longer at an angle but parallel with the body. Keep pushing in the tag until the entire steel dart applicator up to the wooden handle is in the body of the fish (Fig. 11a, b, c). Slowly withdraw the tag applicator parallel to the body of the fish (not upwards towards your own body). Grab the tag and pull slightly to test the strength of the tag. If the tag doesn’t feel secure, cut it out and use on another fish. Following the tagging, it is recommended to observe the fish in a live tank for at least 15 minutes to monitor the behavior of the fish. When releasing, it is preferred that the fish be captured and released without the use of a net, as the tag can easily become entangled and cause greater damage at the incision site. A step-by-step field manual for satellite-tagging sablefish using Method 1 can be found in Appendix 1.

Method 2

Take the measurement (FL) of the fish. If the fish is of the predetermined appropriate tagging size, proceed with tagging. Using crimping pliers, or simply your hand if preferred, hold the piercing needle and push the needle through the dorsal side of the fish, inserting on one side, about an inch below the fourth dorsal fin ray and exiting through the other side of the fish (Fig. 12 a). Piercing through to the opposite side of the fish may require some force (Fig. 12 b). Leave the needle in the fish and feed the long end of monofilament through the fish by pushing it through the hollow piercing needle (Fig. 12 c). The other end will be attached to the tag. Pull the needle the rest of the way through the fish (Fig. 12 d) and remove it from the monofilament. The monofilament should still be strung through the fish at this point. Slip a crimp sleeve onto the monofilament protruding through the fish and pull excess line through fish and crimp sleeve. Be sure to provide enough of a loop so that the tag is close to the fish but does not contact the dorsal fin or tail once both ends of the mono are joined. Slip the short end of monofilament through the crimp sleeve in the opposite direction that the long end is oriented. Crimp the crimp sleeve with the pliers (Fig. 13). Crimps should be made on both ends of the crimp sleeve, about 2-3 mm from the ends. Any excess monofilament may be cut. A step-by-step field manual for satellite-tagging sablefish can be found in Appendix 2.

Laboratory Sampling

Method 1

Two fish in the round were purchased from a commercial fishing vessel on 1 May 2011 to practice tagging Method 1. Both fish weighed 9 kg or greater, a large size for sablefish. It had been recommended to not only tag sablefish > 85 cm FL, but fish of larger girth, of which a heavier weight is indicative of. After scientists became proficient at tagging the dead fish, two live sablefish were tagged with dummy SeaTag MODs using Method 1 on 5 May 2011 at the Auke Bay Laboratories (ABL) and were held for approximately 1,300 days for observations. These fish will be referred to as fish #1 and fish #2 from here on. Due to the difficulty of obtaining live samples, both live tagged fish were 56 cm FL, admittedly too small for actual tagging in the field, and are not accurate representatives for obtaining unbiased results. Nonetheless, these fish were the only option available and thought to be good “worst case scenarios” of the feasibility of this new method of tagging sablefish. Daily observations and photos were recorded for the duration of time the tags stayed attached to the fish, with occasional

observations following tag detachment to assess the incision site. Observations were noted of the following: basic fish behavior, buoyancy issues caused by the tag, healing or worsening condition at the tag incision site, and any other obvious physical stresses as a result of the tag.

Method 2

Two live sablefish were tagged with SeaTag GEOs using Method 2 on 1 May 2014 at the ABL and have been held for over 240 days for observations. Again, due to the difficulty of obtaining live samples, tagged fish were of inadequate field tagging size (both fish were 57 cm FL), but thought to be the best "worst case scenarios" for determining the feasibility of this new attachment method. Due to the similar nature of the behavior of the fish and tag incision sites following tagging, these two fish will be referred together as one from here on. The same daily observations and photos were taken as with the fish tagged using Method 1 in 2011. Fully functioning tags were used to gather tag performance data and to test the battery life of the tags.

Field Sampling

Sablefish were tagged with PSATs on the 2012, 2013, and 2014 NMFS summer longline surveys in the AI, BS, and GOA from 1 June through 26 August. Fish > 85 cm FL were tagged with SeaTag MODS in 2012 (n = 43) and with SeaTag GEOs in 2013 (n = 27) using Method 1. Fish > 80 cm FL were tagged with SeaTag GEOs in 2014 (n = 43) using Method 2. Tags were programmed to collect data every minute, and were evenly divided to pop-off the fish on 1 January and 1 February of the year following tagging. Therefore, tags were to remain on the fish anywhere from 5 to 9 months, depending on when they were initially tagged. These pop-off dates were chosen as times when we felt confident sablefish would be spawning or preparing to spawn, and would theoretically provide locations where sablefish were spawning. Tagging was conducted by 10 different NMFS scientists.

RESULTS

Laboratory Sampling

Using Method 1, fish #1 retained its tag for over 900 days, and fish #2 for 71 days. The tag in fish #2 completely dislodged from the fish. This would happen if the darthead didn't properly lock behind the pterygiophores during tagging, meaning it was just holding in the muscle tissue of the fish and would eventually work its way out of the fish after some time. This

is especially problematic in the soft-fleshed sablefish. Both tagged fish using Method 2 retained their tags for approximately 150 days. Tags utilizing Method 2 were used in the field before the desired testing period of 180 days was reached in the laboratory. However, due to the successful first 2 months and because the tags were unexpectedly received before the 2014 survey, the tags were deployed on the survey during the laboratory testing period.

Laboratory Observations

Method 1

Observations of Tagged Fish #1

While both fish were 56 cm FL, fish #1 had a noticeably smaller girth and appeared to be of lighter weight. Immediately following tagging, fish #1 displayed normal behavior, sitting on the bottom of the tank (Fig. 14). The fish did not appear to favor either one side or the other while swimming and any buoyancy issues caused by the tag were not evident. There was noticeable bruising on the opposite side of the dorsal fin of the tag, as well as bruising near the head on the same side of the body as the tag. Three days following tagging, fish #1 appeared to be behaving normally. The incision site was less inflamed. There was still bruising on the opposite side of the dorsal fin from the tag insertion site (Fig. 15). Six days following tagging, the incision site appeared to be healing and was not as bright red. In addition, the bruising on the opposite side of the dorsal fin and the near the head were smaller (Fig. 16). Nineteen days following tagging, the incision site was still noticeably red, but the bruising on the opposite side of the dorsal fin and near the head was gone. Twenty-five days following tagging, the incision site appeared unchanged, neither worsening nor healing shut. These conditions remained the same until 60 days following tagging. At this point, the tag became noticeable on the opposite side of the dorsal fin where the tag insertion occurred. By the 83rd day following tagging, the dart head of the tag had completely worked itself through to the outside of the fish on the opposite side of the dorsal fin in which the tag was inserted. The tag and fish have remained in this condition up to the present day. The fish appears to behave normally, sitting on the bottom of the tank, swimming, and eating as expected.

Observations of Tagged Fish #2

Immediately following tagging, fish #2 displayed normal behavior, sitting on the bottom of the tank. The fish did not appear to favor either one side or the other while swimming and no buoyancy issues caused by the tag were evident. The incision site was red and noticeable, but there did not appear to be any advanced tissue tearing or irritation around the site (Fig. 17). Five days following tagging the incision site was still noticeable but there was no increase in redness or irritation. It was difficult to tell if the tag was straining dorsally on the fish (Fig. 18). There was no aggressive behavior towards food when placed in the tank. Twelve days following tagging, the incision site had become noticeably worse. It appeared as if the tag was straining dorsally, toward the dorsal fin. As a result, the incision site did not seem to be healing. There was also some dark discoloration around the incision, which looked like a "stress" spot (Fig. 19). Eighteen days following tagging there wasn't any change in the damaged incision site, and it appeared slightly less inflamed. Twenty-six days following tagging the injured incision site had worsened. There appeared to be dead or infected skin that had white coloration surrounding the incision site. The darthead could be seen inside the fish, and most of the external skin covering has been torn away (Fig. 20). This essentially told us that the tag was not inserted properly and was being held within the flesh of the fish and not locked behind the pterygiophores as it should be. There was also increased bruising around the incision site. Thirty-four days following tagging, the injured incision site was still severely damaged and had gotten worse. The entire base of the dorsal fin had become red and appeared stressed. The darthead was visible, as most of the external skin covering had been torn away (Fig. 21). These conditions persisted until the tag was shed from the fish 71 days following tagging. It is interesting to note that 32 days following tag shedding (103 days following initial tagging), the injured tag incision site had completely healed and there were no visible effects of the tagging. Figure 22 is a picture of fish #1 and #2 comparing their range of injuries due to proper and improper tagging, 50 days following tagging.

Method 2

As with the fish used in the lab testing Method 1, both fish tagged using Method 2 were not ideal tagging size (57 cm FL and a small girth). Nonetheless, both tagged fish displayed normal behavior immediately following tagging, sitting on the bottom of the tank. The fish did

not appear to favor either one side or the other while swimming and no buoyancy issues caused by the tag were evident. The incision sites made by the needle on both fish were clean and did not show the physical injuries seen in the Method 1 tagged fish. There was no bruising, open wounds, or wear as a result of the tag (Fig. 23). Daily observations will not be discussed here, as there was no significant behavioral or physical change at the tagging site on either fish over time (Fig. 24). While photos of Method 2 tagged fish aren't very clear, they still convey the clean tagging sites.

Field Deployments

A successful PSAT performance means that the tag remained on the fish until its programmed pop-off date and successfully transmitted its release location. Of the PSATs deployed in 2012 using Method 1, only 20 out of the 43 (47%) were successful; also using Method 1 only 4 of the 27 (15%) PSATs in 2013 performed successfully. Using Method 2, 25 of 43 (58%) PSATS deployed in 2014 were successful. Of the 23 tags from 2012 that did not perform successfully, 8 reported before their programmed release date, and 15 did not transmit any data. In 2013, 8 tags reported before their programmed release date, and 15 did not transmit any data. The 2014 PSATs have shown to have the highest success rate of tag retention in the wild: only 6 (14%) tags released early and transmitted data before their programmed release date, and 12 were not heard from. Tags not heard from (no data transmitted) indicate that the tag release mechanism malfunctioned, the battery died, or the tag was hung-up underwater and never reached the surface.

This success rate is lower than other scientists have experienced using Desert Star PSATs (Marco Flagg, Desert Star, pers. comm.), as well as similar tags made by other manufacturers. In a review of the performance of PSATs, Musyl et al. (2011a) found that out of 731 deployed PSATs, 79% reported data. However, of those tags, only 18% met their pop-off date, while 82% detached early. It is important to note that this is a summarization of PSATs used on multiple species taxa across various habitats and using different attachment methods. However, it does indicate that finding a good attachment method is a common problem.

Receiving data before the tag's release date is likely the result of early tag shedding due to faulty tagging, poor tag retention, or possibly because of death of the fish. While a fish death could be from a number of reasons, admittedly, a likely cause could be from unknown effects of

the tagging procedure. However, this is also speculating that a dead fish would float to the surface. To never hear from a tag after releasing it on a fish could mean many things: the tag may have had internal programming problems, water may have infiltrated the tag therefore interfering with either the release mechanism or the electronics that tell the tag to release, the antenna of the tag could have been damaged or broken off therefore not allowing data to transmit, the battery in the tag may have died therefore not allowing the tag to release, the tag may have experienced biofouling, or the tag may have gone to depths beyond those capable of the tag. Unfortunately, the true reason for the tag not reporting will never be known.

DISCUSSION

This report provides descriptive methods and a brief overview of the results following the first tagging of a deep-water, high latitude fish, sablefish, with PSATs. The success rate of deployed tags were below expectations, especially considering the cost of the tags and satellite usage. Small individuals may have problems with relatively large tags, and in the history of the use of PSATs, sablefish are one of the smallest species to be fitted with PSATs. While PSATs have become increasingly smaller in size, the tag:fish weight ratio is still a matter of concern. In order to minimize the amount of tag loss and to ensure the least amount of disruption to the normal behavior of the fish, the choice of the best attachment method of the tag is critical. It is likely that the tag attachment method used in 2012 and 2013 did not perform as well as the attachment method used in 2014. This could be due to handling time, invasiveness of the tagging method, tagger experience, and duration of tag attachment in the field.

The first consideration for conducting a tagging feasibility study is the stress imposed on the fish during tagging due to handling. Handling causes a stress response and it is important to minimize the amount of excessive trauma due to handling. Different tagging methods have varying degrees of handling times, therefore it critical to choose a method of tagging that requires minimal handling by the scientists. Physiological research has shown that fish remain stressed for a prolonged period after handling; for example, levels of lactic acid may be elevated for more than 24 hours after stressing the fish at certain temperatures (Wendt 1965, 1967; Wendt and Saunders 1973). Stress can lead to altered behavior and possibly even delayed death. Therefore, the handling time during the tagging procedure should be minimized to ensure better

survival and the least amount of stress in the fish. Handling time begins with the catching of the fish, which for the sablefish in our study consisted of the retrieval of hooked fish on longline gear from depths upwards of 1,000 m. Hence, fish that are to be tagged have already undergone a physically stressful experience before being held on deck and tagged. Laboratory studies have shown that immunological suppression occurs in sablefish subjected to capture-related stressors (Lupes et al. 2006). We know from the 10% tag return rate of our conventional tagging that sablefish can physically handle the stress of being hooked and brought up from depth, tagged, and released (Echave et al. 2013). However, we don't know what happens with the remaining 90%. It is likely that handling of the tagged fish in this study is a contributing factor to the lower than expected success rate. The methods presented in this document for satellite tagging are more physically invasive with a longer handling time than conventional T-bar anchor tagging. While Method 2 has shown to be the preferred tagging method based on tag retention success, there does not appear to be a preference towards either method in order to improve handling time. Measuring the handling time between the two methods is difficult due to other variables biasing the results, such as the amount of tagging experience between different scientists. Training in the lab is the best way to develop methods that minimize handling time.

The second consideration when conducting a tagging feasibility study is the physical invasiveness of the tagging procedure and the subsequent health of the fish. All tagging procedures are invasive, beginning with the application process to attach the tag and ending with potential health problems for the fish subsequent to the tagging process itself. Externally attached tags must breach the skin and musculature, therefore infection and wounds at the attachment point and incision site are not uncommon. Heavy tags and the materials used for attachment may also cause deep cuts into the muscles and skin, promoting further infection of the fish, or causing the tissue to be necrotic and prevent normal healing. Histopathological studies on the effects of disc-dangler tags on Atlantic salmon (Morgan and Roberts, 1976), dangling tags that are attached by wire to the fish, revealed that external tags of these types can leave severe traumatic wounds, which may lead to secondary infection. This is a likely scenario with Method 1, as the incision sites did not appear to heal closed in the lab tagged fish. The incomplete healing of the incision site during the life of the fish may affect the normal behavior of the fish or lead to mortality and biased results. Following the 2012 and 2013 tagging seasons, Method 2 was introduced to try and improve tag performance. The goal of switching to this new methodology was to minimize

the expected loss due to tagging error, in addition to a reduced likelihood of infection and wounds at the tag incision site. Method 2 essentially follows the harness method used tagging Atlantic salmon, but uses just one insertion site instead of four (Lacroix 2013). Tagged Atlantic salmon are smaller than our desired tagging size of sablefish, so it was thought to be an improved and overall less invasive tagging procedure than Method 1, and would help reduce the possibility of infection at the tag incision site. The incision site of the tag using Method 2 was noticeably smaller (12 gauge needle vs. a 1-inch incision). Based on observations of the incision sites of the lab fish and the increase in successful tag performance in 2014, Method 2 appears to be a much less invasive tagging method.

The third consideration when conducting a tagging feasibility study is knowing the survey design and experience of the taggers. For cost-effective research and reliable statistical analyses, it is crucial that fish survive the tagging procedure and that neither the tag nor the tagging procedure influence the survival rate of the fish. The number of early reporting tags provides clear evidence of improper tagging. Having such a high number of scientists conducting the tagging likely contributed to a higher percentage of faulty tagging (observed by data received soon after tagging). Ten scientists were used (each year) during the field sampling of this study, and due to the nature of our survey design, a high number will continue to be used in any future work. Whenever a high number of personnel are used to conduct a study that involves a tagging procedure that is not practiced or carried out a high number of times, one would expect tagging error and should therefore make the methodology as foolproof as possible. This was a main motivator for the switch from Method 1 to Method 2. The high number of early reporting tags suggested the need for a simpler tagging method, and one that was less invasive. Method 2 has proven to be a more adaptable method for a study involving a high number of scientists. In addition to more simplified tagging methodology, training in the lab is the best way to alleviate tagger error. More lab tagging practice in the future is necessary.

Many tagging studies aren't properly conducted due to the high cost of tags, and this feasibility study is no exception. While it is beyond the scope of this paper to discuss the actual tag performance (i.e., success rate of data transmissions, accuracy, and formatting of data received, etc.), it is important to acknowledge that tag performance may have skewed the assessment of the effectiveness of the tagging methodologies that were used. This initial feasibility study proved that sablefish can be tagged with PSATs, but that ongoing observations

of tag success due to the attachment methodology used, along with necessary adjustments, could increase the success of this type of tagging. While the first two years satellite tagging sablefish using Method 1 were met with only moderate success, early evidence suggests that Method 2 will result in improved tag retention. A constant struggle exists between the need for smaller, more sophisticated tags and tags that can operate and collect data for longer periods of time. The general problem is that tag size and life are determined largely by the size of the battery. As technology continues to improve, the use of this type of tagging will expand to a broader range of species and habitats. At the start of this project, searches in the literature found that the majority of PSAT tagging was limited to larger, pelagic species in temperate waters. This paper provides an overview of the methods and results using PSATs on a smaller-sized, deep-dwelling, demersal, high-latitude species. This should prove useful to scientists trying to investigate the use of PSATs on similar species.

CITATIONS

Atkins, C.G. 1885. The biennial spawning of salmon. Trans. Amer. Fish. Soc. 14, 89–94.

Beverton, R. J. H., and S. J. Holt. 1957. On the Dynamics of Exploited Fish Populations. Chapman and Hall, London.

Block, B. A., H. Dewar, C. Farwell, and E. D. Prince. 1998. A new satellite technology for tracking the movements of Atlantic bluefin tuna. Proc. Natl. Acad. Sci. USA 95:9384 - 9389.

Block, B. A., H. Dewar, S. B. Blackwell, T. Williams, E. Prince, A. M. Boustany, C. Farwell, D. Dau, and A. Seitz, A. 2001. Archival and pop-up satellite tagging of Atlantic bluefin tuna, p. 65-88. *In* J. R. Silbert and J. L. Nielsen (eds.). Electronic tagging and tracking of marine fisheries. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Dewar, H., E. D. Prince, M. K. Musyl, R. W. Brill, C. Sepulveda, J. Luo, D. Foley, E. S. Orbeson, M. L. Domeier, N. Nasby-Lucas, D. Snodgrass, R. M. Laurs, J. P. Holligan, B. A. Block, and L. M. McNaughton. 2011. Movements and behaviors of swordfish in the Atlantic and Pacific Oceans examined using pop-up satellite archival tags. Fish. Oceanogr. 20:219–241.

Domeier, M. L. 2006. An analysis of Pacific striped marlin (*Tetrapturus audax)* horizontal movement patterns using pop-up satellite archival tags. Bull. Mar. Sci. 79:811–825.

Echave, K. B., D. H. Hanselman, and N. E. Maloney. 2013. Report to industry on the Alaska sablefish tag program, 1972 - 2012. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-254, 47 p.

Hanselman, D. H., C. R. Lunsford, and C. J. Rodgveller. 2013. Stock assessment and fishery evaluation: Assessment of the sablefish stock in Alaska, p. 267-376. North Pacific Fishery Management Council, 605 West 4th, Suite 306, Anchorage, Alaska 99501-2252.

Lacroix, G. L. 2013. Population-specific ranges of oceanic migration for adult Atlantic salmon (*Salmo salar*) documented using pop-up satellite archival tags. Can J. Fish. Aquat. Sci. 70: 1011-1030.

Lupes, S. C., M. W. Davis, B. L. Olla, and C. B. Schreck. 2006. Capture-related stressors impair immune system function in sablefish. Trans. Amer. Fish. Soc. 135:129-138.

Morgan, R. I. G., and R. J. Roberts. 1976. The histopathology of salmon tagging. IV. The effect of severe exercise on the induced tagging lesion in salmon parr at two temperatures. J. Fish Biol. 8:289-292.

Musyl, M. K., M. L. Domeier, N. Nasby-Lucas, R. W. Brill, L. M. NcNaughton, J. Y. Swimmer, M. S. Lutcavage, S. G. Wilson, B. Galuardi, and J. B. Liddle. 2011. Performance of pop-up satellite archival tags. Mar. Ecol. Prog. Ser. 433: 1-28.

Musyl, M. K., R. W. Brill, D. S. Curran, N. M. Fragoso, L. M. McNaughton, A. Nielsen, B. S. Kikkawa, and C. D. Moyes. 2011. Postrelease survival, vertical and horizontal movements, and thermal habitats of five species of pelagic sharks in the central Pacific Ocean. Fish. Bull., U. S. 109(4):341-368.

Seitz, A. C., D. Wilson, B. L. Norcross, and J. L. Nielsen. 2003. Pop-up archival transmitting (PAT) Tags: a Method to investigate the migration and behavior of Pacific halibut *Hippoglossus stenolepis* in the Gulf of Alaska. AK Fish. Res. Bull. 10(2):124-136.

Wendt, C. 1965. Liver and muscle glycogen and blood lactate in hatchery-reared *Salmo salar* L. following exercise in winter and summer. Inst. Fresh. Res., Rep. 46: 167-184.

Wendt, C. 1967. Mortality in hatchery-*reared Salmo salar* L. after exercise. Inst. Fresh. Res., Rep. 47: 98-112.

Wendt, C. A. G., and R. L. Saunders. 1973. Changes in carbohydrate metabolism in young Atlantic salmon in response to various forms of stress. Int. Atl. Salmon Symp., Spec. Publ. Ser. 4:55-82.

FIGURES

Figure 1. -- The Desert Star SeaTag-MOD next to a pen for size comparison.

Figure 2. -- The Desert Star SeaTag-GEO next to a pen for size comparison.

Figure 3. -- Photo of a completed Method 1 tag tether displayed dorsally on a sablefish for comparison. This tag tether should be approximately 3 to 4 inches in length.

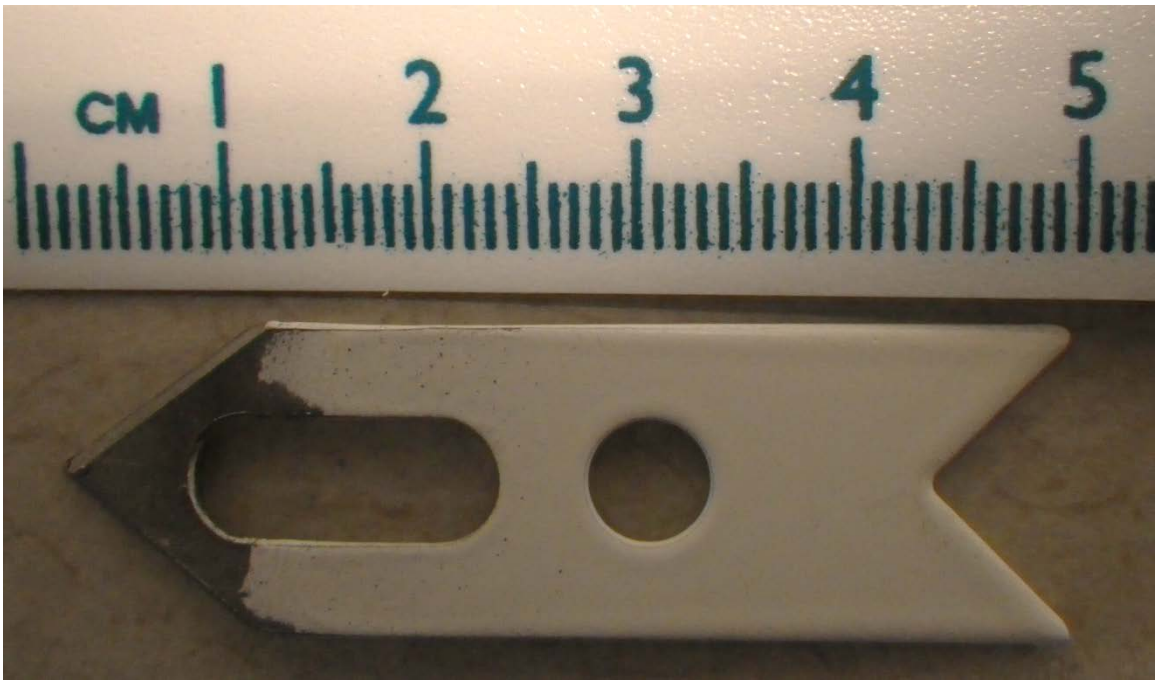


Figure 4. -- Photo of the stainless steel dartheads used in Method 1. These dartheads are 316L surgical grade stainless steel with sharpened edge 1 inch in length.

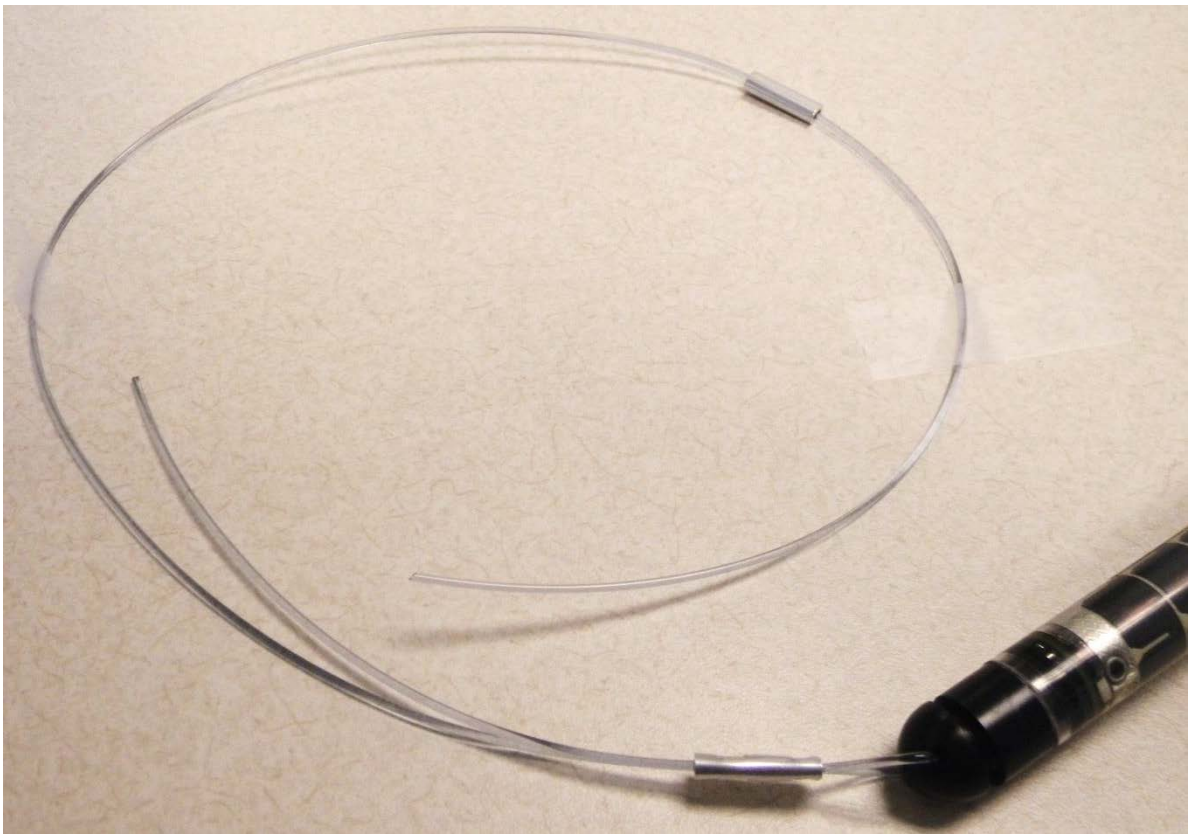


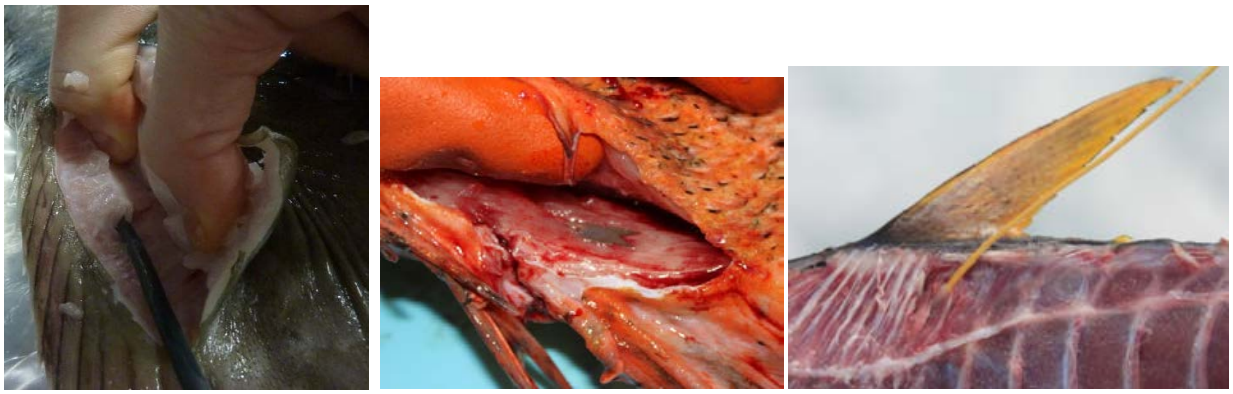
Figure 5. -- Method 2 tag tether before attachment to fish.

Figure 6. -- Photo of the tag applicator used in Method 1, consisting of a wooden handle with a stainless steel dart inserter (Hallprint) screwed in at one end. Entire applicator is approximately 43 cm in length.

Figure 7. -- Photo of the stainless steel hollow loop tag applicator/piercing needle (Hallprint) used in Method 2. Entire applicator is approximately 13 cm in length.

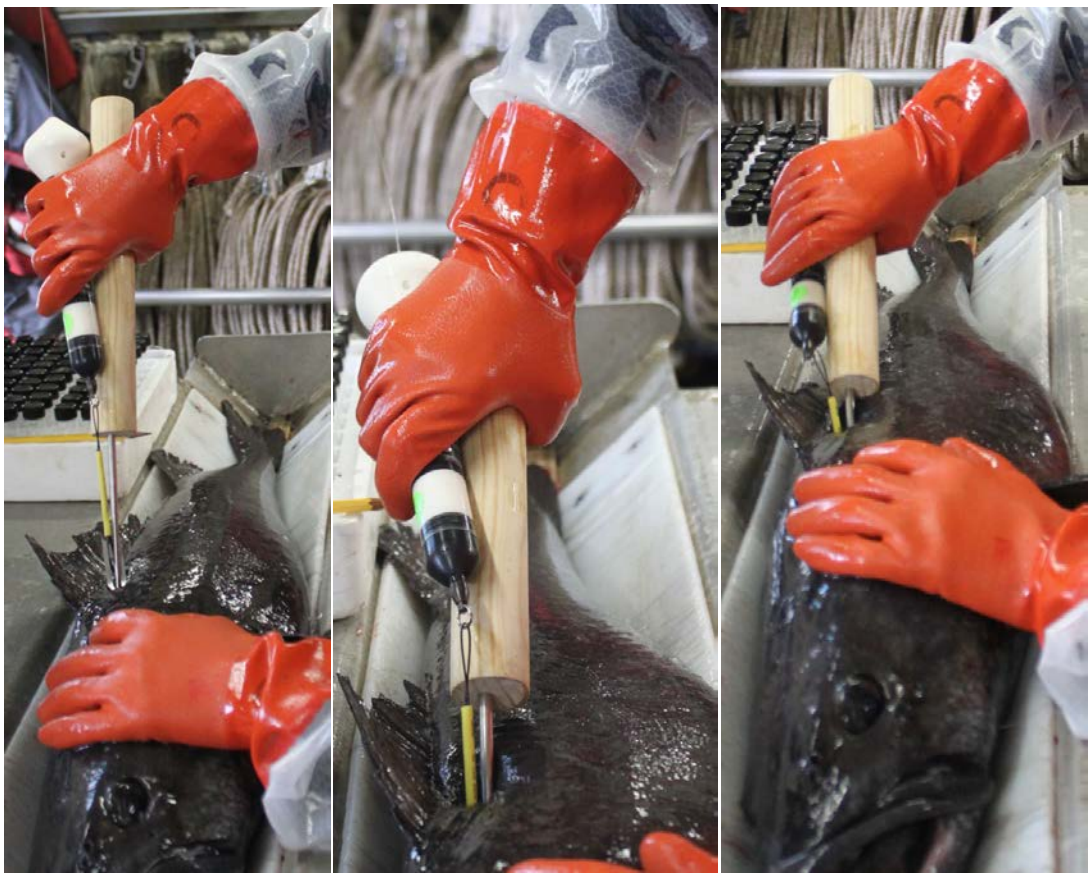
Figure 8. -- Demonstration of the proper incision site for insertion of the tag tether using Method 1. Starting approximately 1inch below the fourth dorsal fin ray, make a 1-inch incision that is angled downward and towards the posterior end of the fish.

Figure 9. -- Demonstration of the proper method of inserting the tag into the fish using Method 1. The tagger must hold the tag applicator at a forty-five degree angle to the fish and insert in a forward and downward direction until feeling and hearing a “pop.”



a. b. c.

Figures 10. -- Photos of various dissected fish showing the proper location of the tag darthead locked behind the pterygiophores. In image a) and c) the side of insertions is shown; in b) the dart hears is shown, on the opposite side of insertion.

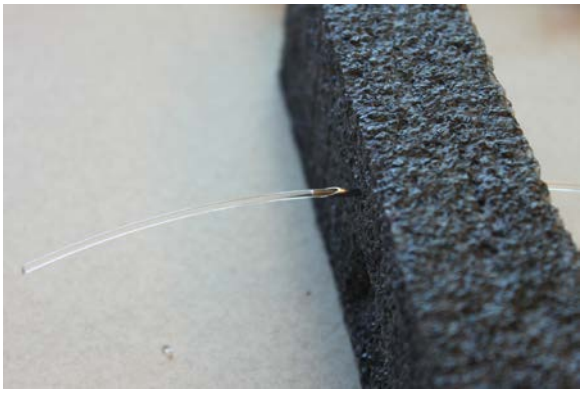


a. b. c.

Figures 11. -- Progression of the methodology of inserting the tag into the fish using Method 1. Note that the entire steel dart applicator is inserted into the fish up to the wooden handle. At that point, the dart head of the tag should be securely in place, then the tag applicator can be slowly withdrawn parallel to the body of the fish (not upwards towards the tagger's body).

a. 

b. 

c. 

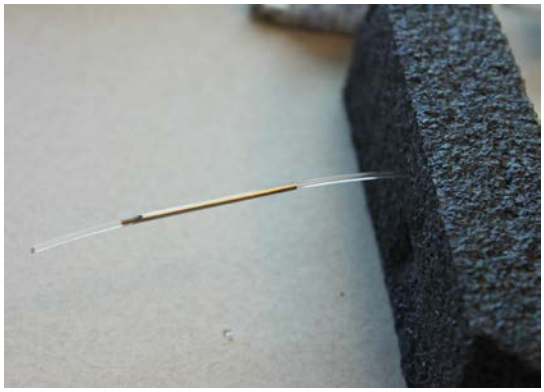
d. 

Figure 12. -- Progression of the methodology of inserting the tag into the fish using Method 2: (a) proper placement of the tagging needle; (b) demonstration of the tagging needle inserted through the fish and ready for mono to be inserted; (c) demonstration of tagging needle in place with inserted mono; (d) demonstration of pulling needle through the fish for removal and mono staying in place for tag attachment. Note that the black styrofoam in figures (c) and (d) are representative of the fish.

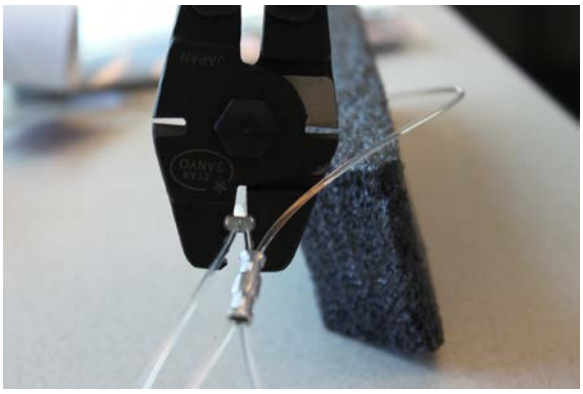
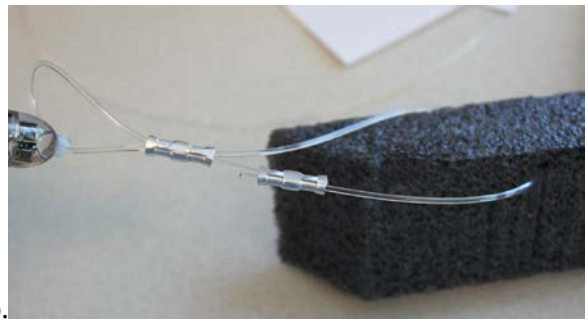
a.  b. 

Figure 13. -- Demonstration of (a) crimping the crimp sleeve after bringing both ends of the monofilament through the sleeve in opposite directions and; (b) attached completed tether using Method 2. Note that the black styrofoam is representative of the fish.

Figure 14. -- Dorsal view of tagged fish #1 immediately following tagging. The fish appeared to behave normally, immediately sitting on the bottom of the tank.

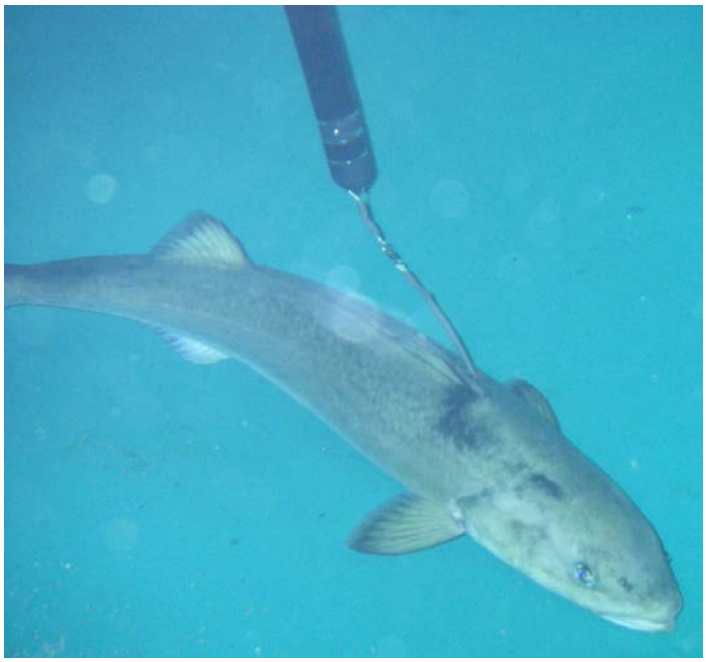


Figure 15. -- Photo of tagged fish #1 3 days following tagging. Note the bruising on the opposite side of the dorsal fin as the tag insertion site and near the head.

Figure 16. -- Photo of tagged fish #1 6days following tagging. In comparison to Figure 15, note the decrease in bruising on the opposite side of the dorsal fin as the tag insertion site, and that the bruising near the head is no longer noticeable. In addition, the incision site appears to be healing and is not as red.

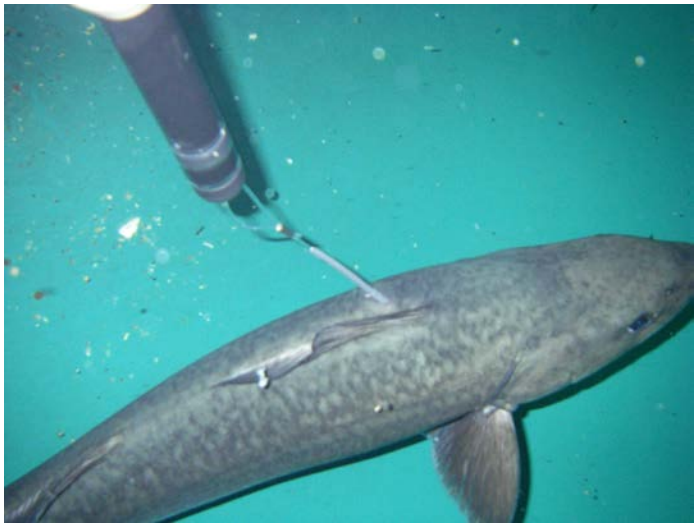


Figure 17. -- Dorsal view of tagged fish #2 immediately following tagging. The fish appeared to behave normally, immediately sitting on the bottom of the tank.

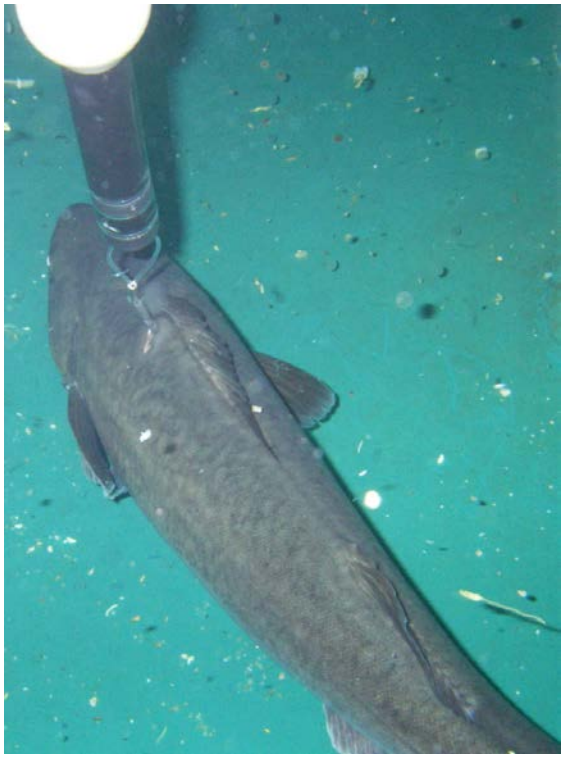


Figure 18. -- Dorsal view of tagged fish #2 5 days following tagging. The tag insertion site does appear to have worsened, but it is difficult to gauge if the tag is straining dorsally on the fish.

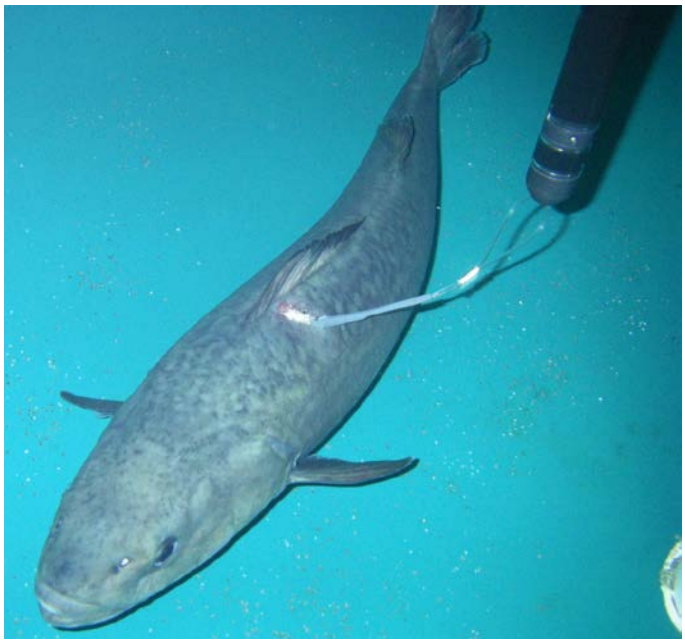


Figure 19. -- Photo of tagged fish #2 12 days following tagging. Note the deterioration at the tag incision site.

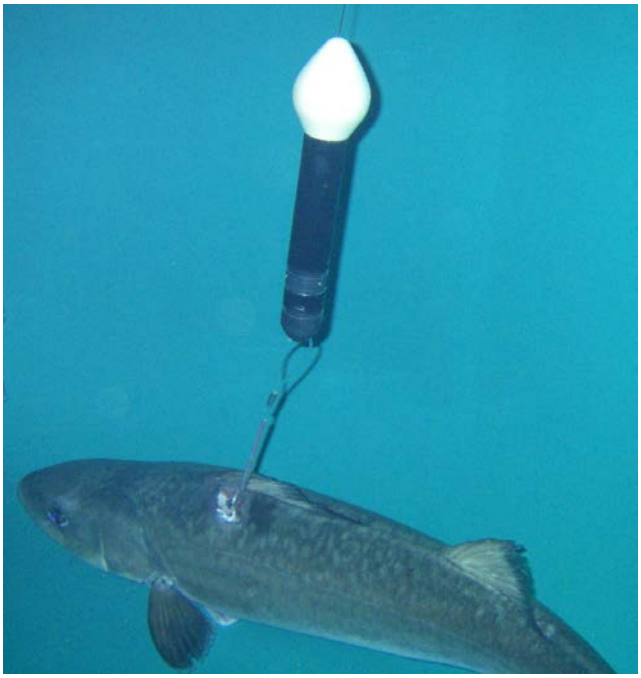


Figure 20. -- Photo of tagged fish #2 26 days following tagging. Note how the dart head of the tag tether is becoming visible due to improper tagging and the deterioration at the tag incision site.

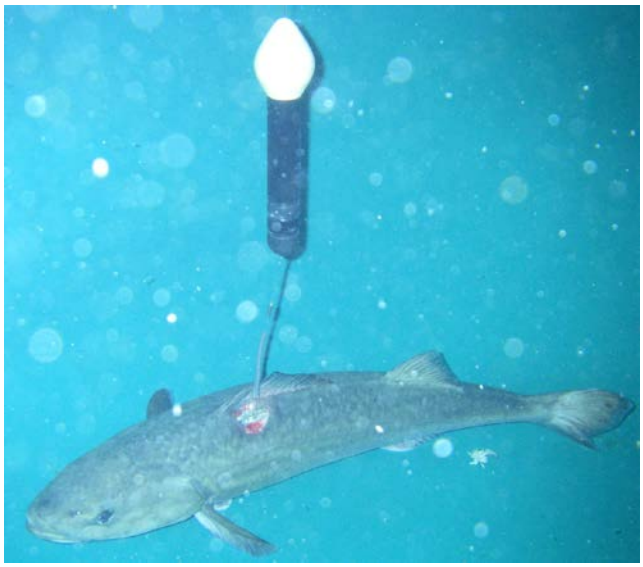


Figure 21. -- Photo of tagged fish #2 34 days following tagging. Note how the darthead of the tag tether is visible and that the tag is not being held in the proper position behind the pterygiophores.

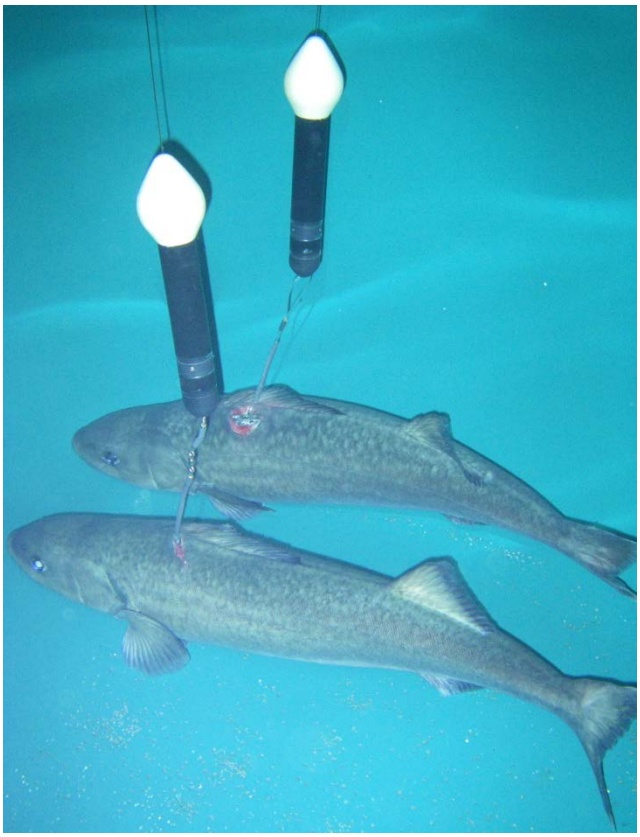


Figure 22. -- A picture of fish #1 and #2 side by side, 50 days following tagging. Note the difference in injury level to the fish due to proper (fish #1, bottom of photo) and improper (fish #2, top of photo) tagging.

a.  b.  c.

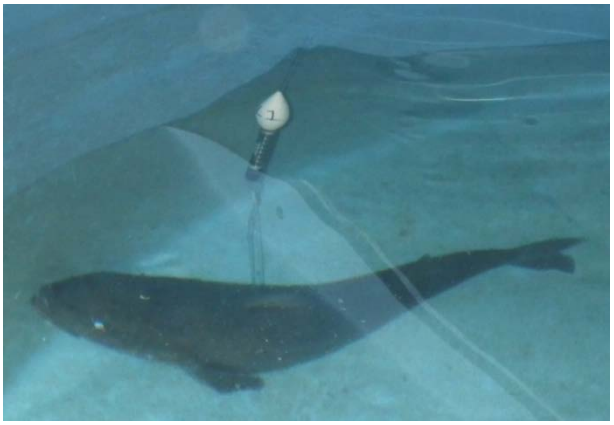


Figure 23. -- Method 2 tagged fish (a) immediately following tagging; (b) 30 days following tagging (fish on right); and (c) 60 days following tagging. Note that there was no unhealthy tissue around needle penetration site.

Appendix 1

Field Guide for Tagging Sablefish on the AFSC Longline Survey Using Method 1

SABLEFISH POP-OFF SATELLITE TAGGING INSTRUCTIONS

Remember to tag any sablefish >85 cm FL, tagging fish on non-tagging skates if necessary. Tags are labeled with the Leg number on the float.

Step 1. Take weight measurement and then place fish on measuring board and record fork length (FL), tag types (SN and P) and numbers (SN on the tag, P on the tether) on the tagging sheet. The tagging sheet to be used is the same as the standard longline survey tag form which are available on the vessel. You can generally tag by yourself, but may need help from the other scientist to keep the fish calm and in place.

Step 2. Liberally apply Betadine solution to the dart head and tether. It will be helpful to have the applicator inserted into the darthead in an accessible spot for the tagger to easily grab with one hand (Fig. 1).

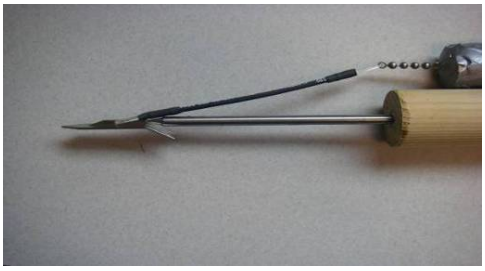


Fig. 1

Step 3. About an inch below the fourth dorsal fin ray, use a scapel to make an incision (<1 in.) no larger than necessary to insert the dart head (better to error on the smaller side). Make this incision slightly angled toward the posterior end of the fish (Fig. 2).

Fig. 2

Step 4. Grab the tag applicator and tag with your right hand, while stablizing the fish with your left (Fig. 3).

Fig. 3

Step 5. Align the dart head into the incision. The dart head should be aiming directly toward the head of the fish, parallel to the dorsal fin. Steady the fish with your left hand. Hold the applicator at a 45-degree angle and jab in a forward and downward direction until you feel and hear a “pop” (Fig. 4). (This will actually take slight force.) This means you’ve gone through and locked under the pterygiophores (fin ray bones, Fig. 5a, 5b).

Fig. 4

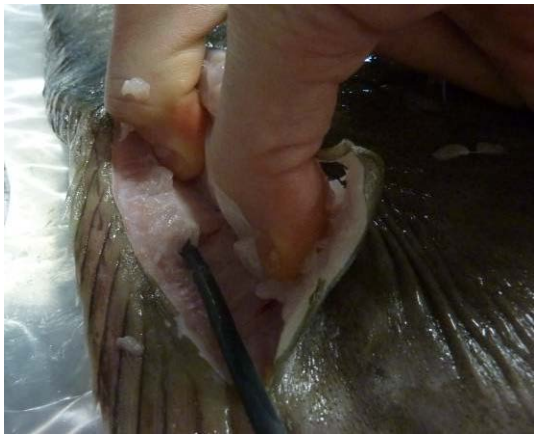


Fig. 5a

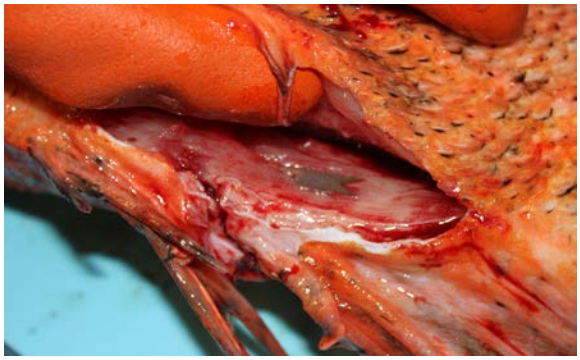


Fig. 5b

Step 6. After you feel as if you've gone completely through the pterygiophores, keep inserting the tag towards the head of the fish. (Note that this is no longer at an angle but parallel with the body.) Keep pushing in the tag until the entire steel dart applicator up to the wooden handle is in the body of the fish (Fig. 6).

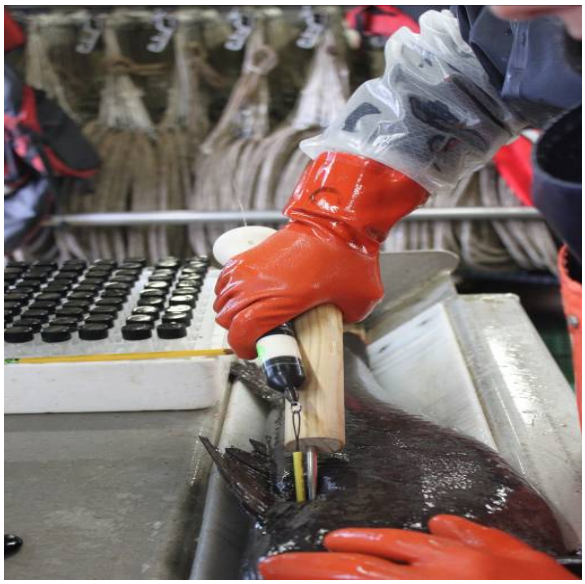


Fig. 6

Step 7. Slowly withdraw the tag applicator parallel to the body of the fish (not upwards towards your own body). Grab the tag and pull slightly to test the strength of the tag. If the tag doesn't feel secure or comes out, you may cut out the tag and use on another fish.

Step 8. Following the tagging, observe the fish in the live tank. It is recommended that the fish be captured and released without the use of a net (Fig. 7).

Fig. 7

Appendix 2

Field Guide for Tagging Sablefish on the AFSC Longline Survey Using Method 2

SABLEFISH POP-OFF SATELLITE TAGGING INSTRUCTIONS

Remember to tag any sablefish >85 cm FL, tagging fish on non-tagging skates if necessary. Tags are labeled with the Leg number on the float. Let the tag "charge" in light for at least ten minutes before releasing the fish.

Step 1. Take weight measurement and then place fish on measuring board and record fork length (FL), tag types (SN and BK) and numbers (SN on the PSAT, BK is the Floy Tag) on the tagging sheet. The tagging sheet to be used is the same as the standard longline survey tag form which are available on the vessel. An EXAMPLE tag sheet is appendixed in the Operations Plan. Help from another scientist to keep the fish calm and in place is helpful.

Step 2. Use the smallest crimp location on the crimping pliers to hold the piercing needle and push needle through the bony musculature about an inch below the fourth dorsal fin ray (Fig. 1). This needs to pierce through to the opposite side of the fish and may be a bit difficult because of the size of the needle, as well as requiring a bit of force. Having the other scientist position the fish will help.

Figure **1**. Insert piercing needle through dorsal musculature using the smallest hole on crimping pliers.

Step 3. Leave the piercing needle in the fish and feed the long end of mono through the fish by pushing it through the hollow piercing needle (Fig. 2). If the mono does not go through the needle, use the cutters on the crimper to cut the line at an angle. After the mono has been successfully pushed through to the opposite side of the fish, pull the needle through the fish and remove it from the mono and set in a safe place (Fig. 3).

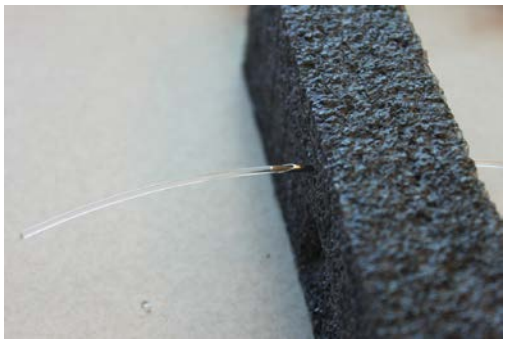


Figure **2**. Feed the long end of mono through the fish by pushing it through the piercing needle.

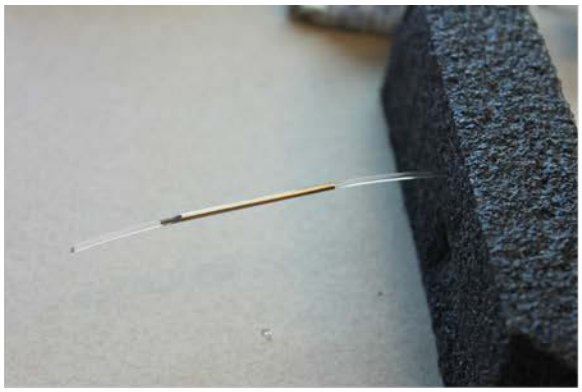


Figure **3**. Pull the needle through the fish and remove it from the mono and set it in a safe place.

Step 4. Slip a crimp sleeve onto the mono protruding through the fish and pull excess line through the fish and crimp sleeve. Be sure to provide enough of a loop so that the tag is close to the fish but does not contact the dorsal fin or tail once both ends of the mono are joined. Slip the short end of mono through the crimp sleeve in the opposite direction that the long end is oriented. Crimp the crimp sleeve with the largest hole on the pliers (Fig. 4). Crimps should be made on both ends of the crimp sleeve, about 2-3 mm from the ends. Any excess mono may be cut.

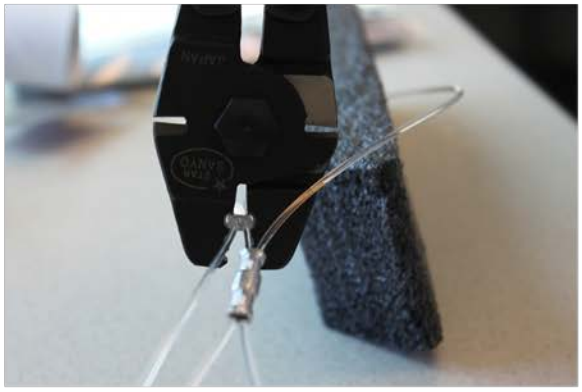


Figure **4**. Bring both ends of the monofilament through the crimp sleeve in opposite directions and crimp on both ends.

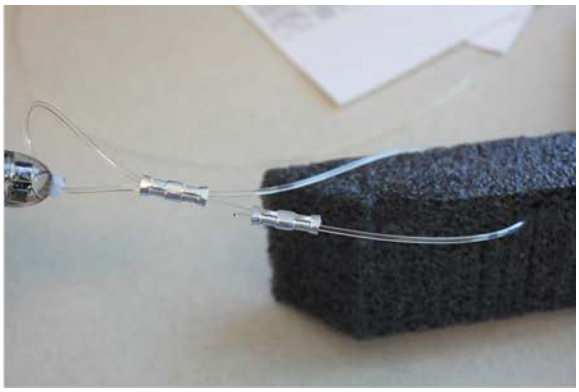


Figure **5**. Completed crimp job. Fish is ready for release.

Step 5. Tag fish with Floy Tag (yellow BK tags) anterior to the satellite tag per usual tagging protocol.

Step 6. Following the tagging, observe the fish in the live tank. It is recommended that the fish be captured and released without the use of a net (Fig. 6).

Figure **6**. Releasing a satellite tagged sablefish.

Step 7. At the end of the day, it is important to clean the crimpers with fresh water. These will rust immediately if not properly cleaned after each use.

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