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ARTICLE

Feasibility of Tagging Walleye Pollock Captured with Hook and Line using External Tags

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Abstract
We evaluated methods of minimizing mechanical injury to Walleye Pollock *Gadus chalcogrammus* when tagging them with external identification tags. Walleye Pollock (20–62 cm FL) were captured with hook and line near Auke Bay, Southeast Alaska, and were tagged with either T-bar anchor tags or lock-on tags, which were anticipated to be used for tagging studies in the Gulf of Alaska and Bering Sea. The tested handling procedures included transferring the tagged fish between live tanks either by using a dip net (dipnetted group) or with wet, bare hands (non-dipnetted group). Sixty percent of the dipnetted fish (63 of 105) died, whereas 12% of the non-dipnetted fish (17 of 138) died. Overall, 50% of the deaths occurred within 7 d after capture, and 89% of the deaths occurred within 10 d after capture. Of the dipnetted fish that died, 68% (*n* = 43) died from dermal infection due to scale loss, whereas 30% of the non-dipnetted fish mortalities were from dermal infection. Additionally, injuries that were recorded as potential mortality factors included fin loss, torn jaws, internal dysfunction, and unknown. All of the fish that received lock-on tags and 93% of the fish that were anchor-tagged developed an infection at the point of tag insertion. Tag retention rates were 99.5% for lock-on tags and 93.7% for anchor tags, and tag type did not affect survival. Use of hook-and-line capture is an effective method for reducing mechanical injury and mortality in Walleye Pollock. Recommended procedures for capturing and tagging Walleye Pollock include the use of hook and line and the use of wet, bare hands (or a similar low-abrasion approach) when handling the fish.

The Walleye Pollock *Gadus chalcogrammus* is the dominant species in the commercial groundfish catch off Alaska. During 2012–2014, the Bering Sea/Aleutian Islands harvest levels of Walleye Pollock averaged 1.38 million metric tons. The Alaskan Walleye Pollock fishery is one of the most valuable in the world, as the 2012 ex-vessel value of the Walleye Pollock catch from the Bering Sea was estimated at $459 million (Fissel et al 2014). Despite the economic importance of Walleye Pollock, many aspects of their biology, including migration, remain unknown, and there is very little tagging information that can be used to estimate the degree of interchange (if any) between Walleye Pollock spawning populations (Tsuji 1989).

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Most of the tagging in the Bering Sea had been completed long before there was any significant directed fishery for Walleye Pollock. For example, from 1966 to 1976, Japanese researchers tagged a minimum of 17,000 Walleye Pollock in the Bering Sea, and only 15 of those fish were recaptured (Yoshida 1979, as cited by Dawson 1989). In September 1982, the Northwest and Alaska Fisheries Center (NWAFC) tagged approximately 7,000 Walleye Pollock that were caught via trawling on the southeastern shelf of the Bering Sea; four fish were recovered, all from the same shelf/slope region (A. Shimada, NWAFC, personal communication cited by Dawson 1989).

The absence of many tag recoveries for Walleye Pollock may indicate either a lack of fishing effort or a high mortality rate of tagged fish caught in nets. Fujioka et al. (1988) reported that the initial capture method may influence the recapture rates of tagged fish. Because of the ecological and economic importance of Walleye Pollock, an improved understanding of their movements and spatial variability is needed to advance stock assessments. Adequate data on the spatial structure of Walleye Pollock stocks are currently unavailable (Winter et al. 2007). Bailey et al. (1999) reviewed the population structure of Walleye Pollock and noted that more information is needed to evaluate the extent of density-driven migration, especially since fine-scale genetic information has failed to resolve population structuring at the scales that are needed for management. Studies of tagged Walleye Pollock can provide a means of determining the extent of migration and stock structure among North Pacific areas—information that is currently lacking. Dawson (1994) noted that Walleye Pollock can move great distances from spawning locations and that meristic and morphometric measures suggest the occurrence of fine-scale population structuring. Tag–recapture information could facilitate an understanding of the relative importance of such movements.

More in-depth information on Walleye Pollock movements in the eastern Bering Sea (EBS) is needed for the development of an age-specific movement model (Miller et al. 2008). The availability of additional information from Walleye Pollock tagging studies would assist in parameter estimation. For example, Ianelli et al. (2011) found a positive relationship between summer mean bottom temperatures in the EBS and Walleye Pollock biomass estimates in the Russian zone. Such apparent environmentally driven movement would benefit from an extensive tagging program. Furthermore, within the U.S. Exclusive Economic Zone in the EBS, the shore-based sector generally relies on Walleye Pollock that are closest to the southern portions of the EBS. Understanding the extent of Walleye Pollock movements relative to their core fishing grounds would help to inform management considerations of time–area closures. The Walleye Pollock fishery is increasingly faced with time–area closures for a variety of reasons, such as avoiding salmon bycatch (Stram and Ianelli 2015). Therefore, an understanding of the effect of changes in fishing patterns relative to Walleye Pollock movement has become more important.

Before large-scale tagging studies can be undertaken, pilot studies are needed to determine the best methods of Walleye Pollock capture, handling, holding, tagging, and release. Two tagging feasibility studies that used nets to capture Walleye Pollock have been reported. In September 1982, a pilot tagging experiment was conducted with Walleye Pollock that were caught via bottom trawling in the EBS (Shimada 1982). During July 1996, Walleye Pollock were captured with a purse seine near Unalaska Island, Alaska, and the feasibility of tagging the fish with coded wire tags was evaluated (NRC and NMT 1996). Both of those studies used nets and reported extremely high mortality rates, sometimes near 100% (Branch 2011). Rutecki and Meyers (1992) recommended that to reduce the mortality of juvenile Sablefish *Anoplopoma fimbria*, stress and mechanical injury during and after capture could be minimized by using the hook-and-line capture method and by avoiding the crowding of fish in holding tanks, thereby minimizing physical contact.

Unlike the previously reported studies, the present study involved the use of hook and line instead of nets to capture Walleye Pollock. We tested two types of external tag (lock-on tags and anchor tags), and we assessed the effects of capture and handling procedures on Walleye Pollock mortality and tag retention over time in order to develop a protocol for the capture, handling, and release of the fish with an appropriate tag. Although we evaluate the results of an original study that was conducted in the 1990s, this paper is relevant given the continued key uncertainties about Walleye Pollock stock structure and the degree to which their movement affects management (Hulson et al. 2013). Tagging, if accomplished successfully, would be a valid and direct means of delineating stock boundaries.

METHODS

The study was conducted in the vicinity of Auke Bay, Alaska (Figure 1), during June 16–December 4, 1992. On June 16–17, the National Oceanic and Atmospheric Administration (NOAA) Research Vessel *John N. Cobb* (28.4 m long) was used to locate schools of Walleye Pollock, and the ship remained positioned over them for sampling. Walleye Pollock were captured by using hook-and-line gear consisting of a medium-weight sportfishing rod and a level-wind reel loaded with monofilament line; the line was equipped with four size-4, long-shanked J-hooks baited with squid and was weighted with a 28-6 lead sinker. This gear configuration had been successfully employed for capturing other groundfish in nearshore waters from small boats. The gear was fished at depths of 25–30 m below the surface. The mesh in the dip nets was knotless. All fish were caught in wind-protected waters during calm conditions.

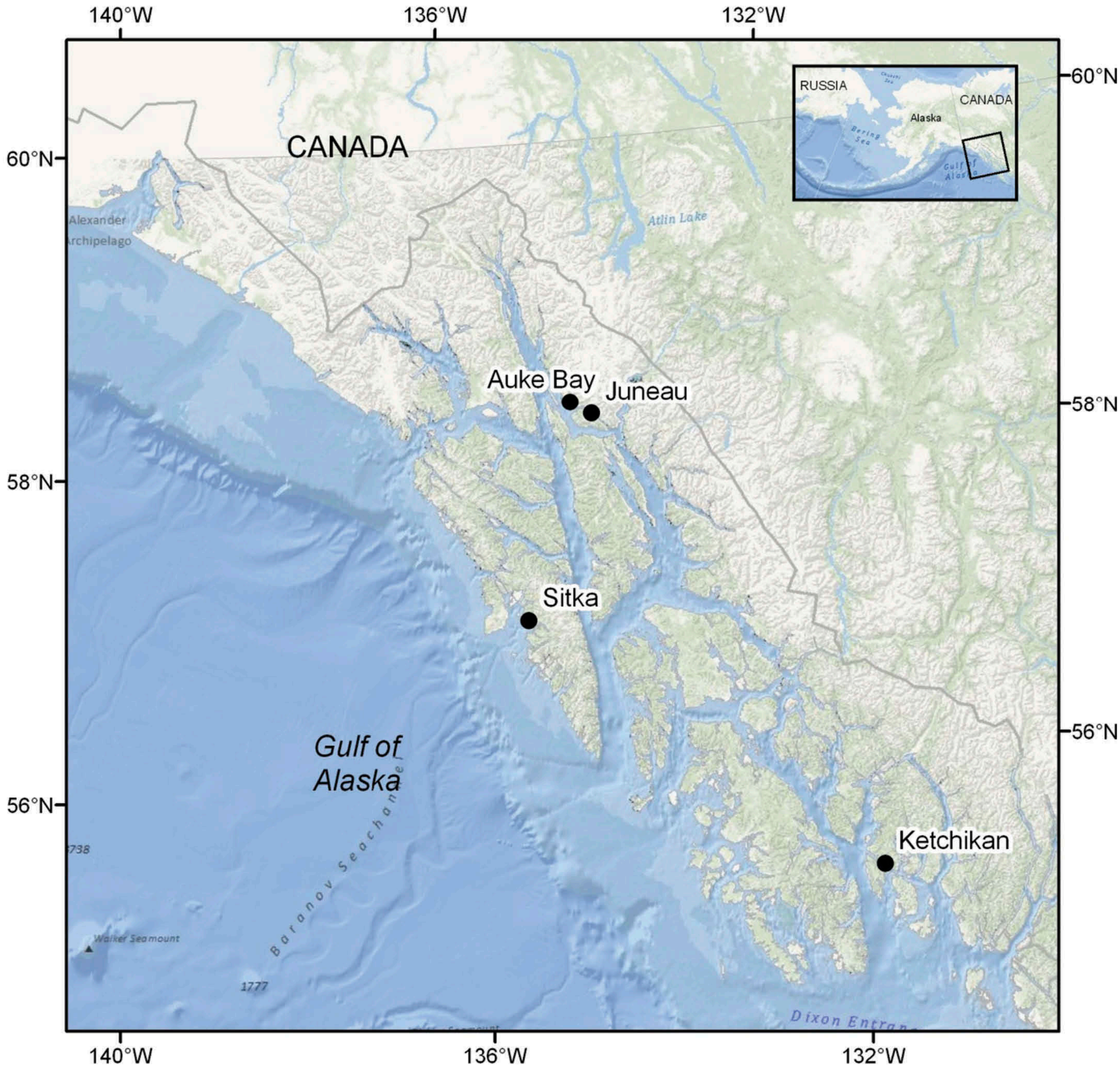

FIGURE 1. Study location in Southeast Alaska, where the feasibility of applying external tags to Walleye Pollock was evaluated.

Most (92%) of the Walleye Pollock that were captured for the experiment were less than 40 cm FL (juvenile size; Figure 2). Age was not determined for the fish. Captured fish were carried to live tanks aboard the vessel by holding the fishing line (not the fish), which prevented the fish from touching any hard surface, such as the side of the vessel. The hook was removed with hook-out pliers after the fish was placed in a live tank. During the handling procedures, two transfer methods were used that later appeared to have a marked effect on Walleye Pollock survival: (1) the use of a dip net to transfer the fish between containers and (2) the use of wet, bare hands (i.e., without dipnetting) to transfer the fish between containers. The chi-square test for independence was used to test the null hypothesis that survival was independent of handling method. Statistical significance was evaluated at the α level of 0.05.

With the dipnetting method, Walleye Pollock in the live tanks aboard the vessel were dipnetted twice: first from a

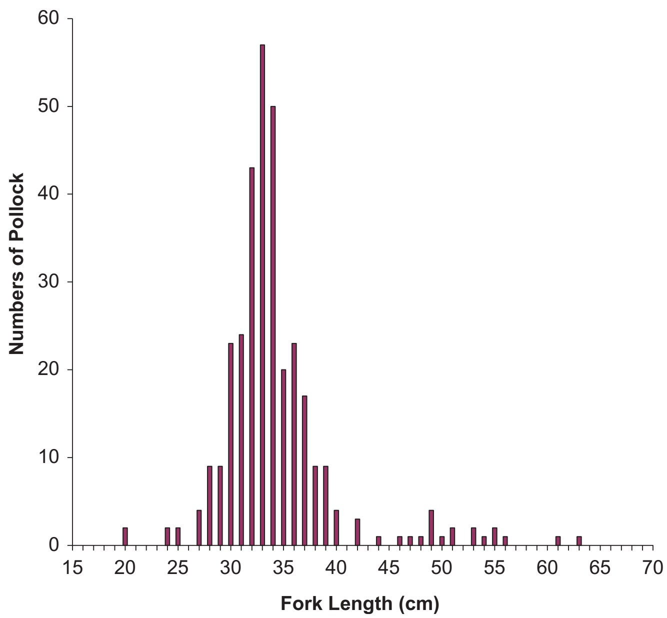

FIGURE 2. Length frequency distribution of Walleye Pollock that were used in the tagging feasibility study.

live tank for tagging and then from a live tank to chest coolers (94.6 L) for transfer to the holding tank at the laboratory. For the non-dipnetting method, the fish were moved without the aid of a dip net; wet, bare hands were used to capture the fish and hold them for tagging. A crane was used to lift each live tank off the vessel, and then a forklift transported and lowered the live tank directly into a large circular holding tank at the laboratory. The live tank was then gently tipped over, allowing the fish to swim from the live tank into the holding tank.

The tagging procedure was performed by two scientists and took place as soon as possible after capture on the vessel; tagging methods were identical for all fish. A fish was removed from a live tank by carefully placing the bare left hand over the fish's eyes and the bare right hand posterior to the first dorsal fin; the fish was then placed on a wet, calibrated board for FL measurement to the nearest centimeter. During tagging, all surfaces (including the hands) were kept wet with seawater to prevent the fish from contacting a dry surface. Only fish that appeared healthy and uninjured were tagged; all others were discarded.

Two tag types were used: the Floy FT-4 lock-on tag and the Floy FD-67 external anchor tag. The FT-4 lock-on tag was tested because it is more visible than the smaller FD-67 anchor tag. However, initial trials showed that the insertion point made by the lock-on tag was large and likely to affect healing and increase mortality. Consequently, the anchor tag was used for about half of the tagged fish as an added part of the feasibility evaluation.

The FT-4 lock-on tag is about 137 mm long, 2 mm in diameter, and designed so that the two ends lock together. The FD-67 anchor tag is 65 mm long, about 0.3 mm in diameter, and designed to anchor into the fish by a "T" at one end. Anchor tags and lock-on tags are very widely used for tagging fish (e.g., Jagielo 1990; Rutecki and Varosi 1992). McFarlane et al. (1990) provided diagrams and methodology for the use of anchor tags and lock-on tags. The tags are attached differently. The lock-on tag is inserted by using a hollow, stainless-steel needle (3-mm diameter). The needle containing the tag is pushed into the body below the first dorsal fin and is pulled through the fish until a few centimeters of tag show behind the needle. The tag is held stationary while the needle is removed. The tag ends are then locked together over the dorsal fin. The anchor tag is inserted by using a Floy tagging gun. A plunger in the gun pushes the "T" portion of the tag through a slotted, hollow needle (2-mm diameter) that has been inserted into the fish beneath the first dorsal fin. The anchor tag has a tab at the exposed end; in the present study, this tab was cut off in case it resembled a food item, potentially stimulating another Walleye Pollock to try to ingest it. The needle and tagging gun were cleaned before tagging. All of the dipnetted Walleye Pollock were tagged with lock-on tags.

Walleye Pollock were held in a single circular, wooden holding tank (4.7-m diameter; 26,495-L volume). Auke Bay seawater was pumped from a depth of 25.9 m and into the tank at a rate of 49.2 L/min. Tagged individuals were held in the tank to permit easy access for feeding them and monitoring their condition. The tank was covered with black polyethylene overlaid with a blue polyethylene tarp, which prevented direct sunlight from reaching the water surface; however, indirect lighting probably reached the water surface from spaces between the cover and the tank. All Walleye Pollock in the tank were fed pieces of 1-cm cubed squid *Loligo* sp. each day, and any excess food was siphoned from the tank before each feeding time.

Seawater temperature in the holding tank was recorded every 10 min and gradually increased from 7.3°C in June to 9.5°C in August. No temperature spikes, which might have affected the survival of the fish, were recorded. At the depth of Walleye Pollock capture (June 16–17), water temperature ranged from 6.9°C to 7.6°C, salinity ranged from 28.8‰ to 32.0‰, and the dissolved oxygen concentration ranged from 2.3 to 8.7 mL/L. Salinity and dissolved oxygen concentration in the holding tank were recorded only once (July 10); salinity was 31.59‰, and dissolved oxygen was 3.96 mL/L. Fish that died during the holding period were examined, and their injuries were classified into five categories: dermal infection due to scale loss; fin loss; torn jaws; internal dysfunction; and unknown (Table 3). The experiment ended on December 4, 1992, when tagged Walleye Pollock from the holding tank were released into Auke Bay.

TABLE 1. Survival of Walleye Pollock that received lock-on tags or T-bar anchor tags and that were transferred between tanks via dipnetting or by use of wet, bare hands (non-dipnetting).

Handling method or tag type	Live	Dead	Total
Dipnetting			
Lock-on tag	42	63	105
Non-dipnetting			
Lock-on tag	66	9	75
Anchor tag	55	8	63
Total	163	80	243

RESULTS

Effect of the Different Handling Procedures

The dipnetting and non-dipnetting methods of fish transfer yielded markedly different results. Sixty percent (63 of 105) of the dipnetted Walleye Pollock died, whereas only 12% (17 of 138) of the non-dipnetted fish died (Table 1). Survival of Walleye Pollock was dependent on the handling method (chi-square test: $P < 0.001$). Clearly, survival was much greater using the non-dipnetting method than the dipnetting method. Fifty-four percent of the non-dipnetted fish were tagged with lock-on tags, and those fish had a much lower mortality rate (12%; 9 of 75 fish) than the dipnetted fish, all of which had lock-on tags.

Mortality

Fifty percent of the Walleye Pollock mortality occurred within the first week of holding, regardless of whether the dipnetting or non-dipnetting method was used (Table 2). For fish with anchor tags, 50% of the deaths (4 of 8) occurred by day 5. For dipnetted fish and non-dipnetted fish with lock-on tags, 89% of the deaths occurred by day 10. Thereafter, mortality of both tagging groups declined and remained low until the last two deaths (one dipnetted fish and one non-dipnetted fish) occurred on day 105.

Of the 243 Walleye Pollock in the holding tank, 80 (33%) died before the end of the experiment (Table 3).

TABLE 2. Observed mortality (N_{mort}) of tagged Walleye Pollock in the holding tank according to handling technique (transfer between tanks via dipnetting or by use of wet, bare hands [non-dipnetting]) and tag type (lock-on tag or T-bar anchor tag). All of the anchor-tagged fish were transferred by non-dipnetting. The total number of fish in each group is given in Table 1.

	Lock-on tag								
	Dipnetting			Non-dipnetting			Anchor tag		
Day	N_{mort}	Cumulative N_{mort}	Cumulative %	N_{mort}	Cumulative N_{mort}	Cumulative %	N_{mort}	Cumulative N_{mort}	Cumulative %
<1							1	1	12
1				3	3	33	2	3	38
3	2	2	3						
4	9	11	17						
5	3	14	22	1	4	44	1	4	50
6	11	25	40						
7	7	32	51						
8	19	51	81	2	6	67			
9				1	7	78			
10	5	56	89	1	8	89			
12	2	58	92						
13	1	59	94						
15	1	60	95						
19	1	61	97				1	5	62
32							1	6	75
33							1	7	88
45							1	8	100
50									
69	1	62	98						
82									
105	1	63	100	1	9	100			
Total	63			9			8		

TABLE 3. Days in captivity until death and number of dead Walleye Pollock for each category of mortality. Fish were transferred between tanks via dipnetting or by use of wet, bare hands (non-dipnetting).

	Dipnetting		Non-dipnetting	
Category	Number dead	Days alive	Number dead	Days alive
Dermal infection due to scale loss	43	3–19	5	5–9
Fin loss	15	4–15	2	10–32
Torn jaws	0–3		3	45–82
Internal	5	4–105	0	
Unknown	0–7	<1–50		
Total	63		17	

TABLE 4. Number (percentage in parentheses) of surviving Walleye Pollock that were assigned to each tag infection category at the time of release (1 = no infection; 2 = the flesh was off-color, but there was no open wound; 3 = the flesh was infected, and the wound around the tag site was less than 5 mm in diameter; 4 = the flesh was infected, and the wound around the tag site was greater than 5 mm in diameter). Fish received lock-on tags or T-bar anchor tags and were transferred between tanks via dipnetting or by use of wet, bare hands (non-dipnetting). All of the anchor-tagged fish were transferred by non-dipnetting.

	Lock-on tag			
Category	Dipnetting	Non-dipnetting	Combined	Anchor tag
1	0 (0)	0 (0)	0 (0)	4 (7)
2	8 (19)	20 (30)	28 (26)	21 (38)
3	29 (69)	28 (42)	57 (53)	27 (49)
4	5 (12)	18 (28)	23 (21)	3 (6)
Total	42	66	108	55

Most of the fish that died had more than one type of injury. For instance, several fish in the dermal infection category also showed fin loss. Conversely, the fin loss category included fish with dermal infections. Thus, although fish were placed in categories based on what was considered the main cause of death, the assignments were somewhat arbitrary. The “unknown” category included seven fish with no visible evidence indicating the cause of death. Dermal infection from scale loss was suspected as a contributing factor in the mortality of 68% (43 of 63) of the dipnetted fish that died and about 30% (5 of 17) of the non-dipnetted fish that died.

Seven of the fish that died bore no internal or external evidence for a particular cause of death. Several of those dipnetted fish died within the first 2 d of holding; thus, their deaths may have been due to capture stress (Davis 2002). Because the length distribution had a small range and thus was similar between both tagging groups, FL was not considered a factor affecting the mortality of tagged fish.

Tag-Related Injuries and Tag Retention

Walleye Pollock that received lock-on tags exhibited raw tissue and infection at each tag hole. About half of the fish were therefore tagged with anchor tags in an attempt to reduce the amount of injured tissue. The extent of tissue damage in each surviving fish at the time of its release was assigned to one of four categories: (1) no infection was apparent; (2) the flesh was off-color, but no open wound was apparent; (3) the flesh was infected, and the wound around the tag site was less than 5 mm in diameter; and (4) the flesh was infected, and the wound around the tag site was greater than 5 mm in diameter.

At the time of release, all surviving Walleye Pollock with lock-on tags and 93% of those with anchor tags were infected at the point of tag insertion (Table 4). Category 3 (i.e., a tag wound with infected tissue at the point of tag insertion) was the most common tissue damage category regardless of tag type.

Retention of lock-on tags was excellent. Of the 180 lock-on tags that were used, only 1 tag became unlocked (99.5% retention). Of the 63 anchor tags that were applied, 4 tags were lost (93.7% retention).

DISCUSSION

The results of other tagging studies in which gadoid fish were caught via handlining (Neilson et al 2006) suggest that tags do not significantly impact the survival of Walleye Pollock. Infection of the tag wound and a lack of healing may be common in tagged fish. Many tagged Sablefish have exhibited open wounds at the location of tag insertion when recovered (D. Clausen, NOAA, Alaska Fisheries Science Center, personal communication, 2008). Winter et al. (2007) stated that neither coded wire tags nor T-bar anchor tags had a significant impact on the survival of Walleye Pollock captured in Alaska.

The results of the present study demonstrate that use of a dip net to handle Walleye Pollock resulted in higher mortality than simply using wet hands. The dipnetted fish were all tagged with lock-on tags, which caused a larger wound. Walleye Pollock are less hardy than Pacific Cod *Gadus macrocephalus* or Sablefish and thus are more vulnerable to mechanical injury when nets (e.g., trawls) are used to capture the fish and when dip nets are used to transfer them for tagging. Davis (2002) examined the discard mortality of fish caught as bycatch and stated that capture stress can increase mortality. Of the dipnetted Walleye Pollock that died, dermal infection due to scale loss was suspected to be the primary cause of mortality. The rate of infection emphasizes the need to minimize scale loss so as to prevent a high mortality rate.

Fin loss is the decay and loss of the fin rays and soft tissue at the base of the fin. Several Walleye Pollock had lost the entire caudal fin before dying. Fin loss was likely related to (1) barotrauma resulting from the rapid change in pressure during capture or (2) an accumulation of gas bubbles during the period spent in holding tanks, as evidenced by gas bubbles in the eyes and opercula. Our results are consistent with those of Natural Resource Consultants (1996), who surmised that the short-term mortality of Walleye Pollock maintained in holding tanks after coded-wire tagging was caused by heavy descaling, abrasion, embolism, or a combination thereof.

Death from torn jaws was attributable to infection and starvation. Care must be exercised during removal of the hook to prevent tearing the flesh. Only healthy fish should be tagged—none with torn jaws. If too much pressure is applied by the hands, the non-dipnet handling procedure may cause internal injuries.

In a study by Winter et al. (2007), Walleye Pollock were caught in trawls, and dip nets were used to transfer the fish to holding tanks on the vessel; the survival rate of those fish was low due to scale loss. The results of Winter et al. (2007) are consistent with our findings; therefore, we recommend the following procedures for the tagging of Walleye Pollock. First, hook-and-line gear should be used for capture, and individual fish should be transferred directly from the sea to a small holding tank (e.g., chest coolers of about 95-L capacity). The hook should be removed carefully from the base of the jaw by using pliers; to minimize tissue damage, shaking or jerking the fish to remove the hook should be avoided. The small tank facilitates hook removal and later recapture of individual fish (by hand) for tagging. A fish should be rejected for tagging if it contacts a hard surface, such as the deck or side of the vessel. The fish should be evaluated at least 15 min after capture and prior to tagging to assess whether the individual's condition is suitable. For example, any Walleye Pollock that has visible retention of gas in the gas bladder, that is bleeding from the anus or gills, that exhibits torn jaws, or that fails to orient properly should be rejected. Fish from the holding tank (chest cooler) should be selected by using bare hands and placed on a wet measuring board (or cradle). Clean needles that have been rinsed in an alcohol bath should be used for tagging. After obtaining measurements, bare hands should be used to gently return the tagged fish to the live tank. When tagged fish are released to the wild, care should be taken to lower the live tank into the sea in such a manner that the fish can exit without contacting a hard surface. Finally, anchor tags are recommended because they require less time to apply than lock-on tags and thus can reduce handling time for this sensitive species.

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