Ontario

Catch-and-release angling: A review with guidelines for proper fish handling practices

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Executive Summary

The use of catch-and-release practices by anglers is increasing. This increase is a result of both anglers viewing the process as a conservation technique and also because catch-and-release practices are being mandated by fisheries managers. Despite the widespread use of catch-and-release, there is generally a lack of understanding regarding the mortality caused by the practice and how variation in catch-and-release techniques may affect the level of mortality.

Fortunately, the increase in catch-and-release practice by anglers has coincided with an increase in research examining catch-and-release practices. While most of the studies to date have been species specific, there are general recommendations that can be made based on the available information.

While catch-and-release is physiologically stressful, stress and therefore mortality can be minimized by following some general catch-and-release guidelines. Gear should be appropriate for the species being angled, allowing for quick retrieval. The use of barbless hooks and circle hooks should be considered to reduce the amount of time required to release fish. Air exposure should be minimized and fish should be released quickly. Depth of capture, hooking location and bleeding should be taken into account when deciding on whether or not to release a fish.

When performed correctly, catch-and-release can be successful with minimal harm to the fish and should be encouraged. However, due to the variation among species in response to catch-and-release techniques, it is recommended that further research is needed to create species-specific guidelines.

Sommaire

Les pêcheurs pratiquent de plus en plus la prise et remise à l'eau du poisson vivant. Cette augmentation a deux raisons : les pêcheurs considèrent que la technique va dans le sens de la conservation et les gestionnaires des pêches la prescrivent. Malgré le recours très fréquent à la prise et remise à l'eau, il existe en règle générale un manque de compréhension concernant la mortalité qu'elle engendre et l'incidence que peut avoir la variété des techniques sur le taux de mortalité.

Heureusement, l'élargissement de cette pratique par les pêcheurs a coïncidé avec des recherches poussées dans ce sens. Quoique la majorité des études à ce jour aient porté sur des espèces particulières, il est possible de faire des recommandations d'ordre général en fonction des renseignements disponibles.

Bien que la pêche avec remise à l'eau soit psychologiquement stressante, ce stress et par conséquent la mortalité peuvent être minimisés si on respecte certaines directives générales. Les pêcheurs doivent posséder du matériel de pêche approprié à l'espèce pêchée, permettant ainsi une capture rapide. L'usage d'hameçons sans barbe et d'hameçons circulaires devrait être envisagé afin de réduire le temps de remise à l'eau requis. Le poisson devrait passer un minimum de temps hors de l'eau et être relâché rapidement. Il doit être tenu compte de la profondeur de capture, de l'emplacement de l'hameçon et de la quantité de sang perdu avant de décider si un poisson doit être remis à l'eau on non.

Le poisson sera blessé le moins possible si l'opération de prise et remise à l'eau est effectuée correctement. Cette pratique dans ce cas devrait être encouragée. Toutefois, en raison des différences existant entre les espèces relativement aux techniques de prise et remise à l'eau, on recommande la poursuite des recherches afin d'élaborer des directives particulières aux espèces.

Introduction

Over the last several decades catch-and-release has become a common practice among anglers. In a review of recreational fishing in Ontario, which was conducted in 2000, only 5% of anglers surveyed reported that they did not practice catch-and-release to some extent (OMNR, 2003). Catch-and-release may be practiced either voluntarily or because it is mandated. In Ontario, size limits are used as a management technique in many waters for a variety of fish species. Fish may be required to be released if they are under a minimum size limit, over a maximum size limit or within a protected slot size. Additionally, anglers may voluntarily practice catch-and-release as a conservation technique.

One of the key components to the increased use of catch-and-release practices, both by anglers and fisheries managers, is the assumption that fish which are released actually survive the experience. This assumption comes from the observation that when fish are released after being caught they generally swim away, apparently unharmed. However, research indicates that most mortality occurs some time after release (Muoneke and Childress, 1994), thus fish that appear healthy upon release may later exhibit injuries or distress caused by catch-and-release practices. Given the potential impact of mortality on the success of catch-and-release as a management practice, there is an increased demand to understand the level of mortality caused by catch-and-release and determine how various factors may affect catch-and-release survival.

The impact of mortality caused by catch-and-release practices is often underestimated by both anglers and fishery managers. From a review of 118 catch-and-release studies (Appendix 1), which, in total, involved over 120,000 fish, the average mortality associated with catch-and-release angling was 16.2%. Thus, while many anglers may assume that by practising catch-and-release they are having no impact on the fish population, a significant number of released fish may die. Additionally, many anglers will continue to fish after they have caught their limit under the premise that they will release all further fish caught, however they often do not take into consideration the number of fish which will inadvertently be killed as a result of this practice.

The purpose of this review is to synthesize current knowledge related to catch-and-release angling and provide some guidelines to minimize mortality caused by catch-and-release practices. While tournament angling is increasing in Ontario, this review does not examine the special issues related to tournament practices. However, in some instances, findings from research focused on tournaments are presented, when they can be applied to non-tournament angling situations. Given the special nature of tournament angling, and their increase in popularity, a review of tournament practices should be conducted.

Influencing Variables for Effective Catch-and-Release

Physiological Response

A number of studies have attempted to determine the physiological response to catch-and-release procedures (e.g. Beggs et al., 1980; Gustaveson et al., 1991; Tufts et al., 1991; Ferguson and Tufts, 1992; Cooke et al., 2003a). From these studies a number of general responses can be identified. Extended play time can result in exhaustion, this is characterised by marked acidosis due to the release of protons into the extra-cellular fluid from poorly perfused white muscle (Tufts et al., 1991). Specifically this causes an increase in blood lactate levels and a decrease in extra-cellular pH (Tufts et al,. 1991). Once the fish is landed, air exposure causes the gill lamellae to collapse, causing an almost complete loss of gas transfer. This results in an increase in blood CO_2 levels and a decrease in blood O_2 levels (Ferguson and Tufts, 1992). Exhaustive exercise and air exposure have been shown to produce an increase in cardiac output, with a decrease in stroke volume and an increase in heart rate (Cooke et al., 2003a). While the physiological response of fish to catch-and-release practices is relatively well understood, little is known about the cumulative impact of these sub-lethal stressors.

Some effects of sub-lethal stress caused by catch-and-release are reduced growth, impaired reproductive success and increased susceptibility to disease and pathogens. Clapp and Clark (1989) found that the growth of smallmouth bass was related to the number of hooking events, such that hooking reduced subsequent growth. Mason and Hunt (1967) examined the survival and growth of deeply hooked rainbow trout over a four month period. They found that, of the fish that survived to the end of the experiment, there was no significant decrease in the growth of fish that were released, even for fish in which hooks were left embedded. In examining the effects of catch-and-release on reproductive success, Booth et al. (1994) found that there was no significant difference in the egg survival of angled and non-angled Atlantic salmon. Conversely, Cooke et al. (2000) found that in largemouth bass, which provide parental care to eggs, fish that were angled incurred increased brood predation and increased likelihood of brood abandonment. Similarly, smallmouth bass have been found to have reduced ability to defend their broods after being angled from their nest (Suski et al., 2003). Thus, for some species at least, evidence exists that catch-and-release may result in reduced growth and reproductive success.

In addition to sub-lethal physiological stress, catch-and-release practices could cause injury, which, although initially does not cause mortality, may have detrimental effects. For example, hooks may physically damage gills, jaw, esophagus and eyes. These injuries may inhibit locomotion, feeding or reproduction, all of which may effectively remove previously healthy fish from the population.

Hook Type

Although considerable variation exists between species in the effects of gear type on catch-and-release mortality, several generalizations can be made. While there is some variation among species, the use of circle hooks tends to reduce mortality. Circle hooks differ from traditional J-style hooks in that the point of the hook is generally perpendicular to the shank (Figure 1). Circle hooks have been found to be less susceptible to becoming deeply embedded; however, there is some evidence that, in bluegill, the incidence of eye injuries may be greater (Cooke et al., 2003b). In a review of the effectiveness of circle hooks, Cooke and Suski (2004) found that, the use of circle hooks reduced overall mortality rates by approximately 50%, but that there was variation among species.

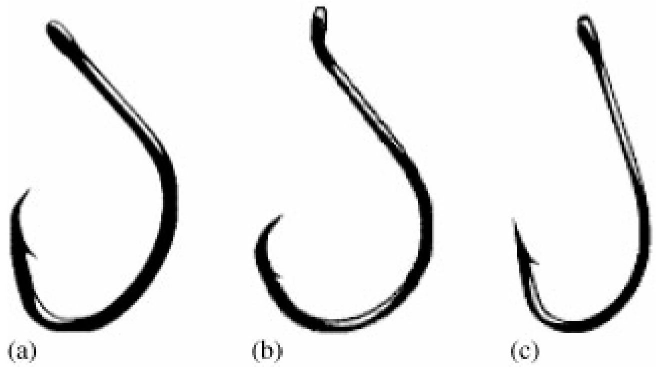

Figure 1. Schematic of two circle hook designs (a,b) and a conventional J-style hook (c) (from Cooke and Suski, 2004).

Barbless hooks are often recommended as an alternative to barbed hooks to decrease catch-and-release mortality. In fact, Manitoba and Alberta have regulated that only barbless hooks may used for angling in those jurisdictions to reduce catch-and-release mortality. Barbless hooks have been demonstrated to reduce handling time through ease of removing the hook, thereby decreasing associated mortality (Cooke et al., 2001). Schaeffer and Hoffman (2002) also demonstrated that the unhooking times of barbless hooks were significantly shorter than barbed hooks, however, the same study indicated that anglers landed 22% more fish using barbed hooks than barbless hooks. Similarly, the use of barbless hooks has been found to significantly reduce mortality in trout (Taylor and White, 1992). It has also been suggested that barbless hooks reduce tissue damage. Thus, while barbless hooks are generally less harmful to fish, anglers may be reluctant to use them because they perceive that catch rates will suffer.

Live vs Artificial Baits

The influence of bait type on catch-and-release mortality has also been examined in some detail. Hooking mortality has been found to be significantly greater with natural baits than artificial bait in striped bass (Wilde et al., 2000). Similarly, worm-baited hooks have been shown to be ingested deeper than artificial lures and flies in bluegill, resulting in increased mortality (Siewert and Cave, 1990). In a comparison of hooking mortality of walleye caught on live and artificial leeches, mortality was 10% and 0% respectively, the use of leeches also resulted in deeper hooking (Payer et al., 1989). Results from smallmouth bass also show 11% mortality when using minnows and 0% when using spinner lures (Clapp and Clark, 1989).

Recently the use of scented artificial bait has increased. It is thought that scented artificial baits may be attacked by the fish in a similar manner as live bait, thus increasing mortality. In support of this hypothesis, Schisler and Bergersen (1996) found that hooking mortality was significantly higher when fish were caught on scented bait than when non-scented artificial bait was used. However, Dunmall et al. (2001) found that there was no effect of scented artificial bait on catch-and-release mortality of smallmouth bass. These studies suggest that the use of organic bait, and possibly scented artificial bait, results in deeper hooking which increases the chance of injury during hook removal and increases the length of time that the fish are exposed to air during hook removal. Thus, catch-and-release mortality can be reduced through the use of artificial bait.

Hooking Location

The location of hooking has been shown to affect catch-and-release mortality. Catch-and-release mortality of white seabass was directly related to hooking location, and all mortalities involved hook damage to the visceral region (Aalbers et al., 2004). Similar results have been found for largemouth bass in which 56% of fish hooked in the esophagus died, while the mortality of fish hooked in other areas was not significantly different than fish that were not hooked at all (Pelzman, 1978). Dextrase and Ball (1991) found that hooking mortality of lake trout was largely restricted to those fish that were deeply hooked. Mortality in northern pike was also greater in fish that were deeply hooked (Dubois et al., 1994). Schisler and Bergersen (1996) reported that mortality of rainbow trout was significantly greater for fish hooked in the gill arches or esophagus than superficially hooked fish, and this increased mortality was attributed to bleeding intensity associated with hooking location. These studies all point to the fact that fish which are deeply hooked suffer increased mortality.

While the increased mortality associated with deep hooking is understood, it is less clear as to whether it is better to cut the line of deeply hooked fish or try to remove the hook, potentially risking further injury and increased air exposure to the fish. Aalbers et al. (2004) examined the growth and survival of white seabass up to 90 days after catch and found that survival of fish released with hooks left in place was enhanced, as compared to fish with hooks removed, but that growth was reduced. When hooks were removed mortality was 65%, compared to 41% when hooks were left embedded. Of the fish in this study that were released with the hooks left in place, 39% had successfully shed the hooks by the end of the study, however, of the hooks that remained in place there was minimal degradation. These results are similar to those found by Mason and Hunt (1967), who examined the effect of hook removal on the survival of rainbow trout up to four months after release. Two-thirds of the fish released without hook removal survived, while only 11.5% of the fish which had hooks removed survived. Additionally, of the fish that survived with hooks left in place, more than half had shed the hooks by the end of the study. Schill (1996) found that cutting the line on deeply hooked rainbow trout reduced mortality from 58% to 36%, and 60%-74% of fish that were released with hooks left in place had managed to discard the hooks by the end of the study. It has recently been suggested that for species such as bass and walleye, it may be possible to reduce mortality caused by deep hooking by removing the hook through the gills (Strange, 20034). However, to date there have not been any empirical studies which have demonstrated the effectiveness of this technique. Thus, despite the relative few studies which have examined the effect of deep hooking on mortality, it appears as though, for some species, mortality can be reduced if deeply hooked fish are released with the hook left in place.

Bleeding

Myers and Poarch (2000), found that the occurrence of bleeding in hooked largemouth bass was related to both mortality and hooking location. Of 19 bleeding fish, 47% died, whereas only 20% of non-bleeding fish died. Bleeding was observed in 48% of fish hooked in the throat and 50% of fish hooked in the gills, whereas only 1% of fish hooked in the mouth bled. Similarly, results from Arctic grayling show that bleeding intensity was related to hooking location, however, in this study there was no relationship between mortality and bleeding intensity (Clark, 1991). Schisler and Bergensen (1996) found that mortality in rainbow trout was significantly related to bleeding intensity. Their model predicted that the probability of mortality increased from 16% with no bleeding to 40% with heavy bleeding. Mortality has also been found to be significantly related to bleeding in cutthroat trout. Mortality was 6.5% in non-bleeding fish and 52.8% in fish that bleed (Pauley and Thomas, 1993). These studies all show that the chance of mortality increases if fish are bleeding, thus, anglers should consider keeping fish that bleed profusely.

Depth of Capture

When fish are caught and retrieved quickly from deep water, injury may result from depressurization. Depressurization can result in over-inflation of the gas bladder, inability to submerge when released, gas embolisms, internal and/or external haemorrhaging and death. Freshwater fish have one of two basic types of swim bladders. Fish, such as carp, esocids, trout and salmon have a duct which connects the swim bladder to the alimentary canal. These fish can expel gas and make buoyancy adjustments more quickly than fish such as, bass, walleye, perch and most panfish which lack a connecting duct and rely on diffusion to deflate their swim bladder. Thus, while susceptibility to depressurization varies among fish species, it has the potential to be a significant source of mortality (Kerr, 2001).

Figure 2. Apparatus used for deep release of lake trout (photo courtesy of D. Reid, Ministry of Natural Resources, Owen Sound)

To release fish that suffer from depressurization a technique known as “fizzing” has been developed to artificially deflate swim bladders by puncturing the swim bladder with a sharp instrument. In a review of “fizzing”, Kerr (2001) suggested that the practice should be discouraged, as significant damage can result from the procedure, and that fishing deep waters (5-6 m) should be restricted if fish are intended to be released. Kerr (2001) also reviewed several alternatives to “fizzing” for releasing fish caught from deep water. These involved lowering fish back to the depth they were caught at for release, by means of a retrievable weight or submersible cage (Figure 2). While little investigation has gone into determining the effectiveness of these alternatives, they are recommended over fizzing. To prevent potential decompression, catch-and-release angling for species in deep water should be avoided.

Temperature

Evidence suggests that catch-and-release mortality is directly related to water temperature, with mortality increasing at extreme temperatures. In a seasonal comparison of hooking mortality of bluegill, Muoneke (1992b) found that mortality was greater in the summer when water temperatures were highest. However, this study did not account for other variables, such as differences in feeding rate or reproductive status, which may have increased mortality during the summer. Similarly, mortality in cutthroat trout has been shown to increase from 0 to 8.6% as water temperature increased from 8°C to 16°C (Dotson, 1982). In a meta-analysis of black bass mortality associated with tournaments, a strong relationship was found between water temperature and both pre-release and post-release mortality (Wilde, 1998). Research from walleye tournaments indicates that mortality increases with water temperature and suggests that tournaments should be limited to the spring and fall (O’Neil and Pattenden, 1992), or when water temperatures are cooler than 15.6°C (60°F) (Boland, 1994). Wilkie et al. (1997) examined the post-exercise physiology of Atlantic salmon at 12°, 18° and 23°C, and found that physiological recovery was slowest at 12°C, however, there was significant mortality at 23°C. This result suggests that warmer temperatures facilitate recovery but that extremely high temperature increases mortality.

Nuhfer and Alexander (1992) found that mortality increased with water temperature in brook trout that were bleeding from the gills or throat area as a result of hooking. Mortality has also been found to increase with water temperature in smallmouth bass (Cooke and Hogle, 2000), largemouth bass (Gustaveson et al., 1991; Meals and Miranda, 1994) and striped bass (Nelson, 1998). Interestingly, Bettoli and Osborne (1998) found that catch-and-release mortality in striped bass was linearly related to air temperature but not water temperature, suggesting the temperature during air exposure may be more important in determining survival than actual water temperature. These studies demonstrate that catch-and-release mortality increases with temperature and special care should be taken with fishing during extremely warm weather.

There has been a similar concern with releasing fish that have been angled during ice-fishing and exposed to cold temperatures. It has been suggested that eyes and gills can be damaged from freezing on extremely cold days. However, studies examining catch-and-release survival of walleye during ice-fishing found no evidence of damage or mortality caused by exposure to cold temperatures (Ellis, 2000). Thus, while brief exposure of fish to cold temperatures may not cause mortality or damage, it is best minimize the time that fish are kept out of the water when ice-fishing.

Type of Landing Net

Despite the widespread use of landing nets by anglers there has been relatively little investigation into the damage caused by their use or which of the available types of net result in the lowest injury to fish. Generally, it is recommended that the use of landing nets be limited as it is thought to increase fin damage, and remove the protective mucus layer, thus increasing susceptibility to disease. Barthel et al. (2003) examined the effects of landing net mesh type on injury and mortality in bluegill. They quantified the effects of netting for a 168 h period after capture and found that there was zero mortality in fish that were landed without a net while fish that were landed with a net experienced a mortality rate of 4 to 14%. There was also increased pectoral and caudal fin abrasion and dermal disturbance (scale and mucus loss). Of the four types of landing net mesh types compared (rubber, knotless nylon, fine knotted nylon and coarse knotted nylon), the knotted mesh types resulted in greater injury and mortality than rubber or knotless mesh. Thus, injury (and therefore mortality) can be reduced if the use of landing nets is limited to those instances where their use is required to safely land and control fish to prevent mechanical injury. However, when the use of a landing net is required or preferred, it is best to use one made of rubber or knotless mesh.

Figure 3. Muskellunge being handled using a cradle (photo courtesy of S. Kerr, Ministry of Natural Resources, Peterborough)

To assist in handling large fish (e.g. muskellunge), the use of cradles is often suggested to minimize stress to the fish. Cradles generally consist of mesh strung between two poles to fit the body shape of the fish (Figure 3). The use of cradles enables fish to be restrained in the water while allowing for the removal of hooks, additionally, a tape measure can be incorporated into the construction of the cradle allowing for the fish to be measured while remaining in the water. Although there have been no scientific studies examining the benefit of using cradles for large fish, their use is generally accepted to be beneficial (Smith, 2001).

Air Exposure

Ferguson and Tufts (1992) found that there were direct effects of air exposure duration on mortality of rainbow trout. Rainbow trout that were chased for approximately 10 min had a survival rate of 88%, however this fell to 62% for fish that were subsequently exposed to air for 30 s and survival was only 28% for fish exposed to air for 60 s (Ferguson and Tufts, 1992). Cooke et al. (2001) examined the effect of handling time on injury and cardiac disturbance of rock bass. While air exposure did not result in any mortality, bradycardia (decreased heart rate) was observed during air exposure and cardiac output increased after fish were returned to the water. Simulated angling (fish were chased for 30 s) resulted in increased cardiac output and arrhythmia (irregular heartbeat). Fish that had 30 s of air exposure required 2 h for full cardiac recovery while fish that were exposed to air for 180 s required 4 h to fully recover (Cooke et al., 2001). These studies demonstrate the detrimental effects of air exposure, and highlight the need to reduce handling time and air exposure during catch-and-release.

Recovery Time

In addition to the immediate effect of catch-and-release, fish may not physiologically recover for some time after being released. Beggs et al. (1980) found that angled muskellunge required 12 to 18 h to recover from acidosis caused by angling. Similar recovery periods have been observed for wild Atlantic salmon, which after being exercised for approximately 10 min, were found to have extracellular acidosis which lasted for about 4 h and blood lactate levels which remained significantly elevated for at least 8 h (Tufts et al., 1991). In a comparison of hatchery and wild rainbow trout, Wydoski et al. (1976) found that hooking induced increased chloride levels in the blood and plasma osmolarity changes which recovered within 8 h (Wydoski et al., 1976). Cooke et al. (2003a) examined the cardiac response of largemouth bass to simulated angling events and found that approximately 135 minutes were required for cardiac variables to return to pre-exercise levels. The length of time required for fish to recover from catch-and-release practices may help explain why mortality is often delayed until after release.

Size of Fish

Fish size is thought to be related to catch-and-release mortality because larger fish are more difficult to handle, thus higher mortality may be expected with increased fish size. In support of this hypothesis Meals and Miranda (1994) found that mortality of tournament-caught largemouth bass was significantly greater (29% vs 9%) in fish greater than 18 inches in length when compared to fish that were between 12 and 14 inches in length. Similarly, in a meta-analysis of mortality associated with black bass tournaments, Wilde (1998) found a non-significant, but positive relationship between fish size and initial mortality. However, the increased mortality observed in larger fish in these studies may be attributed to crowding and increased oxygen consumption while fish are stored in live wells and not to an intrinsic relationship between fish size and mortality. There are also a several studies which have examined the relationship between fish mortality and size and have not found any significant relationship (Titus and Vanicek, 1988; Schill, 1996). It is important to note that the studies discussed here have examined mortality and fish size within species and not between species. Intraspecific studies are difficult to interpret because any observed relationship between fish size and mortality may be attributed to other factors which differ between species, such as feeding behaviour and mouth morphology. However, it may be reasonable to expect that large species, such as muskellunge and pike, may be more susceptible to mortality than smaller species. These large fish are often played for longer periods of time and handled longer for photographs, this results in a larger physiological disturbance after angling. Thus special care should be taken when handling large fish to minimize injury and mortality.

Catch-and-Release Guidelines

Most catch-and-release research to date has focused on examining species-specific responses to potential factors which affect mortality. However, due to the large number of studies that have been completed to date, a number of general trends are emerging. Thus, while caution should be used when applying species-specific findings to other species, the following recommendations are, given the available knowledge base, general guidelines to be used to reduce catch-and-release mortality for most species.

Angling Techniques

- Circle hooks should be used as they will minimize the chance of deep hooking.
- Barbless hooks are recommended as they are easier to remove and therefore reduce handling time.
- The use of live/organic bait should be discouraged as it increases the likelihood of deep-hooking.
- The use of artificial lures should be encouraged.
- Fishing lines must not be left unattended as unattended lines have a greater chance of deeply hooking a fish.
- Fishing line used should be appropriate to the species of fish being sought. This will prevent line breaking and reduce playing time.
- Avoid angling during extreme water temperatures, both hot and cold, if you plan on releasing your catch.

Landing a Fish

- Angled fish should be retrieved as quickly as possible to prevent fish exhaustion.
- Fish should be landed by hand where possible.
- Where a landing net is required, it should be knotless and preferably made of soft rubber.
- When landing extremely large fish (e.g. muskellunge), the use of landing cradle should be considered.

Handling and Photographing a Fish

- Keep fish in the water as much as possible to minimize air exposure.
- Never place your fingers through gills or in the eyes.
- Don't hold heavy fish by the jaw as this may damage the jaw and vertebrae.
- Hold large fish horizontally and support its body to avoid damage to the internal organs.
- Use wet hands or wet cloth gloves to handle the fish.
- Have camera ready prior to landing fish to minimize air exposure.
- If possible, photograph the fish while in water.

Unhooking a Fish

- Have longnose pliers available to back the hook out.
- Remove the hook quickly, keeping the fish underwater.
- If the fish is deeply hooked, cut the line and release the fish as quickly as possible.
- Avoid using stainless steel hooks as they take longer to corrode if left in the fish.

Depressurization

- Avoid fishing deeper (5-6 m) waters if you intend to release your catch.
- Consider depth of capture when deciding on whether or not to release a fish.
- Release the fish quickly after it is landed.
- Avoid artificial swim bladder deflation ("fizzing").

Revival

- If there is current, hold the fish upright, facing into the current.
- If there isn't any current, gently move fish back and forth in the water until gill movements return to normal and it is able to maintain its balance.
- When the fish begins to struggle, let it swim away.

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Appendix 1: Summary of findings from catch-and-release studies.

Species	N	Days	% Mortality	Reference
Blue catfish	52	3	5.1	Muoneke, 1993
Channel catfish	214	3	19	Ott and Storey, 1993
Channel catfish	704	6	33	Rutledge, 1975
Channel catfish	14	<1	0	Tilyou and Hoenke, 1992
Flathead catfish	52	3	11.5	Muoneke, 1993
Yellow bullhead	20	<1	0	Tilyou and Hoenke, 1992
Muskellunge		3.5	30	Beggs et al., 1980
Northern pike	242	5-16	0-4.8	Burkholder, 1992
Northern pike	94	4-10	6.4	Falk and Gilman, 1975
Northern pike	185	2	1-33	Dubois et al., 1994
Tiger muskellunge	217	1	9.7	Newman and Storck, 1986
Artic grayling	180	2	0.6	Clark, 1991
Artic grayling	158	4-10	5.1	Falk and Gilman, 1975
Atlantic salmon	300	10-14	0.3-5.7	Warner, 1976
Atlantic salmon	149	5	13	Warner, 1978
Atlantic salmon	177	2-5	4-35	Warner and Johnson, 1978
Atlantic salmon	1221	3-14	5.1	Warner, 1979
Atlantic salmon	20		0	Booth et al., 1994
Brook trout	550	7-10	1-57	Shetter and Allison, 1955
Brook trout	806	1	2.6	Shetter and Allison, 1958
Brook trout	630	2	4.3	Nuhfer and Alexander, 1992
Brown trout	490	14	13.5	Hulbert and Engstrom-Heg, 1980
Brown trout	107	1	0.9	Shetter and Allison, 1958
Brown trout	197		0-28	Shetter and Allison, 1955
Brown trout	215	10	3-7	Barwick, 1985
Chinook salmon	888	4-6	22.1	Wertheimer et al., 1989
Chinook salmon	506	5	21-25	Wertheimer, 1988
Chinook salmon	100	1-5	10	Bendock and Alexandersdotitir, 1991

Species	N	Days	% Mortality	Reference
Chinook salmon	245	5	6-11	Bendock and Alexandersdotitir, 1991
Chinook salmon	3618		11.8	Butler and Loeffel, 1972
Chinook salmon	66	2	9.1	Natural Research Consultants, 1989
Coho salmon	85	35	42-55	Milne and Ball, 1956
Coho salmon	147	2	6.8	Natural Research Consultants, 1989
Coho salmon	4861		18.4	Butler and Loeffel, 1972
Coho salmon	384		69.3	Vincent-Lang et al., 1993
Cutthroat trout	652	30	5.11-5.5	Marnell and Hunsaker, 1970
Cutthroat trout	690	30	3.8	Dotson, 1982
Cutthroat trout	509	10	5-73	Hunsaker et al., 1970
Cutthroat trout	72698		0.3	Schill et al., 1986
Cutthroat trout	578	4	1.37-48.5	Titus and Vanicek, 1988
Lake trout	129	4-10	6.98	Falk et al., 1974
Lake trout	67	2	14.9	Loftus et al., 1988
Lake trout	50	2	10	Dextrase and Ball, 1991
Rainbow trout	100	120	95	Mason and Hunt, 1967
Rainbow trout	1000	3	1-10	Klein, 1965
Rainbow trout	159		11-35	Shetter and Allison, 1955
Rainbow trout	300	120	34.5-82	Mason and Hunt, 1967
Rainbow trout	38	10	5-39	Barwick, 1985
Rainbow trout	574	2	5.7-36	Stringer, 1967
Rainbow trout	65	1-2	20	Faccin, 1983
Rainbow trout	346	1	5.2	Shetter and Allison, 1958
Rainbow trout	900	28	2.1	Jenkins, 2003
Rainbow trout	281	29-34	16	Schill, 1996
Striped bass	576	3	1.87-70.39	May, 1990
Striped bass	307	3	38.1	Hysmith et al., 1992
Striped bass	113	3	0-69	Childress, 1989a
Striped bass	464	14	16-17	Harrel, 1988
Striped bass	215	30-40	15-29	Diodati, 1991
Striped bass	89	>3	14-67	Bettoli and Osborne, 1998
Striped bass	153	3	6.4	Nelson, 1998
Palmetto bass	89	3	1-29	Childress, 1989a
White bass	122	3	0.8	Childress, 1989a

Species	N	Days	% Mortality	Reference
Yellow bass	5	<1	60	Tilyou and Hoenke, 1992
Black sea bass	64	2	4.7	Bugley and Shepherd, 1991
Crappie	15	<1	0	Tilyou and Hoenke, 1992
Black crappie	202	<1	19-77	Childress, 1989b
White crappie	226	6-11	3	Hubbard and Miranda, 1991
White crappie	69	18	29	Childress, 1989b
White crappie	43	3	9.3	Muoneke, 1992a
White crappie	13	≤504	15.4	Colvin, 1991
Bluegill	170	3	1.1-25.3	Muoneke, 1992b
Bluegill	210	3	0-18	Burdick and Wydoski, 1989
Bluegill	75	10	30-88	Siewert and Cave, 1990
Bluegill	200	7	4-14	Barthel et al., 2003
Bluegill	685	3	1.3	Cooke et al., 2003b
Pumpkinseed	175	3	0	Cooke et al., 2003b
Rock bass	80	5	0	Cooke et al., 2001
Black bass			5	Lee, 1989
Largemouth bass	1106	1-2	3-16	Bennett et al., 1989
Largemouth bass	3283	<1	14	Schramm et al., 1985
Largemouth bass	3129	28	32	Seidensticker, 1977
Largemouth bass	261	14	19.4	Archer and Loyacano, 1975
Largemouth bass	1351	6	38	Rutledge and Pritchard, 1975
Largemouth bass	1422	7-23	30	May, 1973
Largemouth bass	1863	19	14.3	Welborn and Barkley, 1974
Largemouth bass		14-21	26.7	Schramm et al., 1987
Largemouth bass	285	60	11.2	Pelzman, 1978
Largemouth bass		2	3.2	Hartley and Moring, 1991
Smallmouth bass	70	7	0-11	Clapp and Clark, 1989
Smallmouth bass	634	20	4.2-47.3	Weidlein, 1989
Smallmouth bass		2	8.9	Hartley and Moring, 1991
Smallmouth bass	458		0-8.5	Bennett et al., 1989
Smallmouth bass	61	2	4.9	Jackson and Willis, 1991
Smallmouth bass	238	3	0	Dunmall et al., 2001

Species	N	Days	% Mortality	Reference
Guadalupe bass	85	3	2.4	Muoneke, 1991
Spotted bass	47	3	8.5	Muoneke, 1992a
Walleye	180	12	1.1	Fletcher, 1987
Walleye	865	5	40	Goeman, 1991
Walleye	47	3	0	Parks and Kraai, 1991
Walleye	2357	3	21	Fielder and Johnson, 1992
Walleye		14-28	5-16	Payer et al., 1989
Walleye	240	2	0.8	Schaefer, 1989
Walleye	123	1	23	Rowe and Esseltine, 2002
Sauger	74	<1	4	Bettoli et al., 2000
Black drum	19	<1	0	Martin et al., 1987b
Black drum	325		0	Martin et al., 1987a
Red drum	171	<1	0	Martin et al., 1987b
Red drum	121	3	4.13	Matlock et al., 1993
Red drum	38	3	44.7	Childress, 1989a
Red drum	968		0.21	Martin et al., 1987a
Spotted seatrout	401	7	37	Hegen et al., 1983
Spotted seatrout	43	<1	20-70	Martin et al., 1987b
Spotted seatrout	52	7-9	0-56	Matlock and Dailey, 1981
Spotted seatrout		7	17-27	Hegen et al., 1987
Spotted seatrout	124	3	7.29	Matlock et al., 1993
Spotted seatrout	127		16.54	Martin et al., 1987a
White seabass	221	90	10	Aalbers et al., 2004

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