Fisheries Research 125–126 (2012) 57–68

Contents lists available at SciVerse ScienceDirect

Fisheries Research

journal homepage: www.elsevier.com/locate/fishres

Physiological and behavioural consequences of capture and retention in carp sacks on common carp (*Cyprinus carpio* L.), with implications for catch-and-release recreational fishing

Tobias Rapp[a,*], Jan Hallermann[a], Steven J. Cooke[b], Stefan K. Hetz[c], Sven Wuertz[d], Robert Arlinghaus[a,d]

[a] Inland Fisheries Management Laboratory, Faculty of Agriculture and Horticulture, Humboldt-University of Berlin, Philippstrasse 13, Haus 7, 10115 Berlin, Germany
[b] Fish Ecology and Conservation Physiology Laboratory, Department of Biology, Carleton University, Ottawa, ON K1S 5B6, Canada
[c] Department of Animal Physiology, Systems Neurobiology and Neural Computation, Humboldt-University of Berlin, Philippstrasse 13, 10115 Berlin, Germany
[d] Department of Biology and Ecology of Fishes, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany

ARTICLE INFO

Article history:
Received 27 July 2011
Received in revised form 20 January 2012
Accepted 29 January 2012

Keywords:
Angling
Stress
Fish welfare
Biotelemetry

ABSTRACT

Common carp (*Cyprinus carpio* L.) captured by specialised carp anglers are often retained in so-called “carp sacks” and released after substantial retention periods of several hours duration. Little is known about the lethal and sub-lethal (e.g., physiological disturbances, behavioural impairments) consequences associated with this practice. In this study, the effects of capture and retention in carp sacks on the physiological status of small hatchery-reared carp were examined at two moderate water temperatures (12 °C and 22 °C) in a laboratory setting, where water quality changes in carp sacks were also studied. A complementary field approach was used to examine the effects of carp sack retention on physiology, tissue damage, short-term behaviour and long-term fate of large feral carp in Dow’s Lake, a lentic section of the Rideau Canal in Ottawa, Ontario, Canada. During retention for up to 9 h, decreasing plasma lactate levels suggested recovery from initial capture stress, yet there was evidence of pronounced primary and secondary physiological stress responses resulting from the combined capture and retention in carp sacks in both the laboratory and the field. In addition, there was evidence of tissue damage in carp retained in carp sacks for long periods. The moderate water temperatures studied did not strongly affect the stress response in carp, and changes in water quality parameters within carp sacks were minor and likely not of biological relevance. Physiological changes were associated with impaired post-release behaviour reflecting a tertiary stress response, but recovery was rapid within a couple of hours post-release. No mortalities occurred in a two month observation period. Our findings indicate that despite being sub-lethally affected by capture and retention, carp are able to recover rapidly with negligible mortality from retention in carp sacks like those used in the present study.

1. Introduction

Angling constitutes one of the physically most demanding forms of exercise fish for fish during natural conditions (Wood, 1991). It can cause alterations in neuro-endocrine functions (primary stress response) and will usually also result in subsequent changes in tissue biochemistry (secondary stress response in blood and muscle; reviewed in Cooke and Suski, 2005; Arlinghaus et al., 2007). Biochemical and physiological demands that exceed a threshold can affect the whole-animal performance (tertiary stress response; Wendelaar Bonga, 1997; Barton et al., 2002). Previous catch-and-release studies have indeed revealed behavioural alterations (reviewed in Donaldson et al., 2008) and other organismal end-points, such as reduced reproductive output (Ostrand et al., 2004) or altered feeding behaviour potentially reducing growth and condition (Clapp and Clark, 1989; Diodati and Richards, 1996; Siepker et al., 2006; Klefoth et al., 2011). In addition to stress responses at various levels, angling can cause further sub-lethal effects to fish, including the appearance of cytoplasmatic enzymes in the blood stream that are indicative of angling-induced tissue damage, as the function of these enzymes is restricted to intracellular spaces and they are only released upon cell defects or death (Morrissey et al., 2005; Moyes et al., 2006; Butcher et al., 2011). Severe injuries and levels of stress experienced during a catch-and-release event can ultimately result in either immediate or delayed mortalities (reviewed in Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Arlinghaus et al., 2007).

Environmental conditions are among the main determinants that influence the level of stress response and affect survival of fish

* Corresponding author at: Department of Natural Resource Management, South Dakota State University, Box 2140 B, Brookings, SD 57007, USA.
E-mail address: tobias.rapp@sdstate.edu (T. Rapp).

0165-7836/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.fishres.2012.01.025

that are caught and released (reviewed in Muoneke and Childress, 1994; Bartholomew and Bohnsack, 2005; Cooke and Suski, 2005; Arlinghaus et al., 2007). In particular, the effect of high water temperature is noteworthy, which can result in elevated physiological disturbances, extended recovery periods and increased mortality rates across many stenotherm cold-water fish species such as salmonids (reviewed in Gale et al., in press), but this may also be applicable to low water temperatures in warm water-adapted fish species (Arlinghaus et al., 2007). Specifically for carp (*Cyprinus carpio* L.) as a eurytherm species that prefers warm water (Blanck et al., 2007) little is known about the effects of temperature on the stress response and survival in a catch-and-release angling context. Pottinger (1998) observed differences in cortisol dynamics between trials in carp angling experiments conducted at temperatures of 4 °C and 15 °C. In this study, cortisol continued to rise for a longer time period after the onset of a stressor in trials conducted at the low water temperature compared to the high water temperature (Pottinger, 1998). These findings indicate that the effect of water temperature on catch-and-release effects in carp demand further study.

Post-capture handling procedures can constitute further stressors to the fish (Cooke and Suski, 2005; Arlinghaus et al., 2007), and it has been shown that these stressors can be cumulative and interactive, intensifying biochemical, physiological and behavioural changes (Killen et al., 2003; Suski et al., 2003), which may delay or inhibit recovery (Cooke et al., 2002a; Suski et al., 2004; Gingerich et al., 2007). Similar to capture itself, the effects of subsequent handling-related stressors on physiology, behaviour and survival can be influenced by environmental conditions such as water temperature (Davis and Schreck, 2005; Gingerich et al., 2007). In specialised carp angling, extended post-capture retention prior to release is one of the most pronounced and long-lasting handling practices. Carp anglers value photographic memories of their catch (Arlinghaus and Mehner, 2003) and in particular trophy-sized fish are often retained when captured during adverse light conditions for photography (i.e., during night) in order to take pictures when conditions have improved to obtain quality photographs (i.e., during daylight). To this end, so-called “carp sacks”, which are collapsible, dark, and knotless mesh bags made of synthetic fibre cloth, are widely used to temporarily retain fish in specialised carp angling. Despite their frequent use, no information is available on the effects of carp sack retention on fish.

Previous research on net retention gear in recreational fisheries has focused on keepnets (Raat et al., 1997; Pottinger, 1997, 1998; Cooke and Hogle, 2000; Schreckenbach and Wedekind, 2000; Gallardo et al., 2010; Butcher et al., 2011), which technically differ from carp sacks in that they have a rigid structure which supports the mesh. Moreover, the net mesh in keepnets is typically rigid and mesh sizes larger compared to carp sacks. Studies with various cyprinid species showed that the effects of keepnet retention on the physiological status are generally minor and often do not exacerbate the physiological stress response induced by capture alone (Pottinger, 1998; Schreckenbach and Wedekind, 2000; Gallardo et al., 2010). Moreover, Pottinger (1998) demonstrated that carp recover from capture during keepnet retention. This was also reported for other retention gear used in recreational angling in other species (e.g., largemouth bass, *Micropterus salmoides*, and walleye, *Sander vitreus*, retention in live-wells) provided that appropriate water quality is maintained (Suski et al., 2004; Killen et al., 2006). In addition, previous studies found no evidence that keepnet retention results in increased mortality rates or long-term consequences for growth in various cyprinid fish species, including carp (Raat et al., 1997; Schreckenbach and Wedekind, 2000). Until now, it is unknown whether the same applies to retention in carp sacks, which, as explained above, differ in shape and design from keepnets. Therefore, it is not appropriate to transfer research results from keepnets to carp sacks without careful evaluation.

The objectives of the present study were to assess whether and to what degree a specialised carp angling event that includes post-capture retention in carp sacks results in a primary, secondary or tertiary stress response, or stress-induced tissue damage. Moreover, our study aimed at studying the effects of a high and low water temperature on the stress response of carp retained in carp sacks after capture. These questions were addressed using complementary laboratory and field approaches. The laboratory experiments were used to evaluate the effects of carp sack retention on the physiological status of small hatchery-reared carp at two different water temperatures (12 °C and 22 °C), and in addition were used to examine changes in water quality parameters during retention in carp sacks as a possible contributor to the stress response in retained fish. The field component was used to assess the effects of retention in carp sacks on fish physiology, tissue damage, short-term behaviour, and long-term fate of large feral carp as they are targeted by specialised carp anglers.

2. Methods

2.1. Assessment of carp sack retention on the physiological status of carp in the laboratory

Two hundred 2-year old mirror common carp (mean total length ± SD: 27.7 ± 2.7 cm) were obtained on 16 October 2007 from the commercial pond aquaculture facility Peitz (Schlepzig, Germany; N52°01′45.25″, E13°53′43.60″) and equally distributed in 4 holding aquaria (~2000 l, 50 fish per tank) in a temperature-controlled laboratory at Humboldt-Universität zu Berlin, Germany. Initial water temperature was 18 °C. During the first 2 weeks, water temperature in the holding aquaria was gradually changed (by a max. of 0.5 °C d^{-1}) to 12 °C and 22 °C in each of two aquaria. The experimental water temperatures were chosen to reflect typical temperatures during spring summer and fall, which are the main seasons for specialised carp angling in central Europe. Carp were acclimated to laboratory conditions over a period of 6 weeks and were fed a commercial diet (Kraftfutter Beskow GmbH, Beeskow, Germany, KM 28/08) twice per day at 2% body weight per feeding.

To assess the effects of capture and retention in carp sacks on the physiological state of the study animals, 10 individual carp from each water temperature treatment (12 °C and 22 °C) were randomly allocated to either a control group, a group that was subjected to simulated capture resulting in physical exhaustion only or one of four different retention treatment groups of 0.5 h, 3 h, 6 h or 9 h after physical exhaustion (N = 120, mean total length ± SD: 27.9 ± 2.7 cm). The 0.5 h retention treatment mimicked short-term retention, e.g., when carp anglers take photographs shortly after capture. The 3 h, 6 h, and 9 h retention treatments correspond to short-, medium-, and long-term retention in carp sacks in a typical specialised carp angling event, e.g., when fish are captured during late evening hours, night or early morning hours and are retained until the next morning when light conditions for photography have improved.

Maximum one fish was netted from an individual holding tank to avoid an influence of sequential sampling on physiological status (Pickering et al., 1982). Control fish experienced no further treatment. Fish in the simulated capture and retention treatment groups were individually transferred into a 200 l tank with identical water temperature as the respective holding tank from which they were netted and subjected to a simulation of capture (i.e., the physical activity associated with the capture process of a hooked fish) by tail pinching the fish for 3 min (e.g., Suski et al., 2004; Killen et al., 2006; Arlinghaus et al., 2009). Fish in all retention treatment groups were