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A brief discussion on the 2% tag/bodymass rule of thumb

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Abstract

In the past two decades the number of researchers using biotelemetry to examine fish behaviour and survival has increased considerably. Associated with this has been a significant amount of literature on the effects of the transmitters on the measures under consideration. Despite this, some researchers still rely on a general rule of thumb, "the 2% rule", to indicate that the tagging protocol did not affect the results of a study. While it is clearly important to minimise the size of a transmitter and disturbance to a fish, such a general rule does little to advance our understanding of tag effects and may even hamper our ability to effectively study fish behaviour. This note will focus on the size specific effects of tags on fish and presents some recent results along with suggestions for future evaluations. We conclude that there is no generally applicable 'rule' for tag/fish size relationship and that the appropriate maximum relationship is driven by the specific study objectives, the tagging method and the species/life stage involved.

Introduction

In the book "Fisheries Techniques" published by American Fisheries Society (AFS) in 1983, and again in the 2nd edition (1996), J.D.Winter recommended that "Fish generally should not be equipped with transmitters that weigh more than 1.25% in water or 2% in air of the fish's weight out of water". Despite the fact that it was meant as a "rule-of-thumb", the recommendation has been widely accepted and used to validate many studies where it is often referred to as the "2% rule". Despite recent recommendations to abandon such a general rule (Brown *et al*., 1999; Jepsen *et al*., 2002), papers are still published in which the authors have not evaluated the effects of electronic tags on the fish, but merely state that they complied with the "2% rule".

We emphasise the need to avoid such a general statement and encourage researchers to be more proactive in establishing appropriate tag to body mass relationships. In the absence of information indicating the appropriateness of tag to body mass relationships it is incumbent on the authors to indicate that the potential effects of transmitters on fish performance are unknown. In this paper we present arguments and evidence against applying one general rule to fish of different species. When considering a tagging protocol, there are several factors that directly affect the performance of a fish, including tag weight in water (excess mass), tag volume, tag position and tag dimensions. Often overlooked, but just as important to consider, is the length and mass of an antenna and the antenna material (Cooke and Bunt, 2001). Equally important is the nature of the question being asked. The consequence of a large tag to a fish may be very different for studies that examine long term migrations (weeks), versus those that are only concerned with movement patterns over a 1-2 day period versus studies on survival or foraging behaviour. As an analogy, we might consider that a 20 kg backpack would considerably affect the performance of an Olympic sprinter, whereas the effect would be almost negligible to a person hiking 12 km on a mountain trail. It is also of importance where the tag is placed in or on the fish. Usually external tags are positioned further from the centre of balance of the fish than internal tags. Thus, external attachment can have additional effects on the balance and hydraulic properties of the fish. We argue that the appropriate tag mass to body mass ratios are relative to the specific objectives of each study and often tag volume, placement, dimensions or the presence of an antenna is more of a limiting factor than tag mass. This paper is not meant to be presenting a review of studies dealing with effects of tagging, but merely as a current comment to the discussion about tag/bodymass ratios. For a comprehensive and recent review of tagging procedures and effects, Thorsteinsson (2002) is recommended.

Tag/bodymass

While studies have shown adverse effects on fish tagged with transmitters heavier than 2% of their bodymass (McCleave and Stred, 1975; Ross and McCormick, 1981; Marty and Summerfelt, 1986; Eiler, 1990; Adams *et al*., 1998; Lefrancois *et al*., 2001), it is clear that there are many exceptions. For example, the swimming performance of rainbow trout (*Oncorhynchus mykiss*) smolts with tags of 6–12% tag/bm ratio (mass of the tag as a percentage of the fish's body mass) was not significantly impaired (Brown *et al*., 1999). In a study of Chinook salmon (*Oncorhynchus tshawytscha*) smolts tagged with 2.6-g dummy transmitters, most fish were well below the 2%ratio, but for some small (<50 g) individuals, the tag/bm ratio exceeded 5% (Jepsen *et al*., 2001). When physiological indices of stress were regressed against tag/bm ratios, no relationship was apparent 1, 7 or 21 days after tagging. The results of field studies suggest that in many cases tag size does not alter the behaviours under consideration. A comparison of recent data from the Columbia River (Schreck *et al*., 2001; 2002) with that of Ledgerwood *et al*. (2000; 2001), indicates that radio-tagged (2-10% tag/bm ratio) and PIT tagged (<1% tag/bm ratio) steelhead (*O. mykiss*) and fall Chinook salmon migrate at the same rate in the Columbia River between Bonneville Dam and the estuary (~180 km). This suggests that there is no compromise in the long term swimming performance of radio tagged fish. Similarly, the estimates of avian predation on the radio tagged smolts (Schreck *et al*., 2001; 2002) and PIT tagged smolts (Ryan *et al*., 2003) in the Columbia River are surprisingly similar, suggesting that the extra size and weight of the radio tag has little effect on predator avoidance.

In another study (Clements and Schreck, 2002), analysis of the effect of the tag size on the survival of hatchery-reared coho salmon (*O. kisutch*) suggests that there was no relationship between tag size and mortality. For fish that were implanted with radio transmitters the mean tag/bm ratio was 2.4±0.1% (mean ± s.e.) both for fish that were assumed to have survived and fish (transmitters) that were detected following predation by cormorants. Similarly, coho salmon were implanted with acoustic transmitters and the fish that were assumed to have survived had a mean tag/bm ratio of 9.2±0.4%, not significantly different for coho salmon that were assumed to have died due to predation (8.2±1.1%). In addition, the estimated estuarine mortality for fish tagged with the larger acoustic tag (70%) was almost identical to that for fish tagged with a radio tag (64%), suggesting that the size of the transmitter had a minimal and not statistically significant effect on predation (Clements and Schreck, 2002).

Few studies have systematically investigated the effects of different tag/bm ratios, and recommendations on maximum ratios often seem to be unfounded statements. Besides stress and growth, tag mass may influence buoyancy, equilibrium, swimming performance, feeding, wound healing, social rank and the propensity of fish to expel tags. Thus, to be able to put forward credible recommendations of tag mass to fish body mass ratios, effects of different ratios on all such characteristics of the fish may be necessary, depending on the objectives and duration of the study. Furthermore, it must be considered that the effects of different tag/bm ratios may depend on species, life stage, fish size, sex, general health of the fish, water temperature, water quality, habitat and tag attachment method.

Many researchers have found that the morphology of a fish species can be the limiting factor for tag size. In regards to internal tagging, this is the case for fish species with an elongated body form, such as eels, or vertically or laterally compressed fishes such as flatfishes or angelfish, where there is very little room in the body cavity. In predatory fish, the body cavity is usually larger and the body wall is more flexible than in omnivorous or planktivorous species (Jepsen *et al.*, 2002). For external tagging, it is important that the tag is not causing permanent postural disequilibrium and consequently irregular swimming (Thorsteinsson, 2002). For fast swimming species, the drag resistance of external tags can lead to reduced swimming ability, depending on the size, position and shape of the tag. Thus, fish morphology is important in determining the possible effects of tagging. For a number of species, tag volume and shape more than the tag/bm ratio limits the tag size. In these cases compliance with a tag/bm ratio of 2 % would be of little value in ensuring a minimal impact of the transmitter to the fish.

In cases when the transmitter can be placed internally or externally in a reasonable manner related to the morphology of the fish, the effect of the transmitter on buoyancy must still be considered. The transmitter will affect the buoyancy of the fish, and the ability of the fish to compensate for the additional mass is important for the discussion of maximum tag/bm ratios. Some fish, typically those associated with the substrate, are negatively buoyant while others have buoyancy aids such as oils, watery tissues and poorly ossified skeletons or swim bladders that match their densities to the water (McNeill, 1993). Many pelagic fish maintain a minimum forward cruising speed to generate enough lift to prevent sinking, for example elasmobranchs, scombrids and thunnids (e.g. Jobling, 1995). Most teleosts possess gas-filled swim bladders. In general, the swim bladder is approximately 5% of the volume of marine fishes, and approximately 7% in freshwater fishes, providing enough lift for neutral buoyancy. A fish with a gas-filled swim bladder can remain neutrally buoyant at different depths by secretion or absorption of gas to keep the swim bladder at constant volume as the ambient pressure changes (McNeill, 1993). In more primitive fish (such as salmonids and anguillids), the connection between the swim bladder and gut is retained as an open tube, and the fish are able to take in air at the surface and to vent it as they ascend upwards in the water column (physostomatous fish) (e.g. Bone and Marshall, 1982). The great majority of teleosts lose this open connection at early life stages, and the adult swim bladder is entirely closed (physoclistous fish). The swim bladder is filled either before the connection is lost, or by secretion of gas from special cells in its wall, a process that requires some time. While physostomatous fish may be neutrally buoyant most of the time, recent research suggests that most physoclistous fish are negatively buoyant much of the time (Arnold and Greer Walker, 1992), thus allowing for vertical migrations that would be impossible if the fish had to remain neutrally buoyant at all depths.

A neutrally buoyant tag can be made by increasing tag size or decreasing the density of components. Some neutrally buoyant archival tags are produced (Star-Oddi) and it would be very interesting to test the performance of fish tagged with such tags. Usually, tag size rather than mass is minimised and, thus, the tag represents additional weight in water which will affect the buoyancy of the fish. Perry *et al.* (2001) studied the buoyancy compensation of Chinook salmon smolts tagged with surgically implanted dummy tags. The results showed that even fish with a tag representing 10% of the body mass were able to compensate for the transmitter by filling their swim bladders, but the following increase in air bladder volume affected the ability of the fish to adjust buoyancy to changes in pressure. If a surgically implanted tag fills up a substantial part of the body cavity of a physostomatous fish, the fish may not be able to compensate, because there is simply not room enough for expansion of the swim bladder.

In a study of sea bass (*Dicentrarchus labrax*), Lefrancois *et al.* (2001) concluded that there is a certain threshold tag/bm ratio where the energy demand of a tagged fish increases rapidly. In this case fish with "tag weight in water/fish bodyweight ratio" of 0 and 1% did not significantly increase metabolic oxygen demand, but when this ratio was increased to 4%, the fish had to use 28% of their total usable power to maintain buoyancy.

In fish that are naturally negatively buoyant, such as mackerels and tunas, part of the energy expended in swimming is used to provide hydrodynamic lift in order to keep the body from sinking (Jobling, 1995). This lift increases by increased swimming speed, and additional mass by a tag may thus necessitate an increase in the swimming speed. Arnold and Holford (1978) suggested that for plaice (*Pleuronectes platessa*), that have no swimbladder and are negatively buoyant, the additional mass of a tag will lower the energy expenditure by holding station on the bottom in a current of a given speed and also result in a reduction of work against the lift force exerted by the current. The addition of the tag could thus benefit a plaice opposing a current on the sea bed.

In conclusion, the buoyancy regulating mechanisms of the fish determines the ability of the fish to adjust for the additional mass of a transmitter, and thus also the maximum size of transmitter that can be used for that fish. Physostomatous fish can regain buoyancy relatively fast by gulping air at the surface. The time until buoyancy is regained depends on the fish size, transmitter mass, physiology of the fish, water temperature and the depth the fish is held at. In order to judge the possible effects of the tags on buoyancy of the fish, and consequently on factors like behaviour, energy expenditure and growth, the weight of the tag in both air and water should be given.

Conclusion

There is no generally applicable "rule" for tag/fish size relationship and the appropriate maximum relationship is governed by the specific study objectives and the species/life stage involved. Thus, we recommend that all studies involving telemetric tags should include some kind of evaluation of tagging effects, preferably systematic investigations like the studies of Moore *et al.* (1990) and Peake *et al.* (1997). When laboratory studies that show little or no effect on the fish by the tag, caution must still be taken when evaluating the results of field studies as differences in environmental conditions and/or fish condition at tagging may lead to significant changes in behaviour and/or survival. It is important that the effects studied are relevant for the objectives/conclusions of a study – a study of swimming capacity or feeding cannot be used to draw conclusions about effects on growth or survival. An alternative method of validation is to compare the results from multiple simultaneous studies using different methods to monitor fish behaviour or comparing the results within one study: is the behaviour significantly different the first hours or days after tagging than later in the study? This may also give information on the duration of the tagging effects and on which results should be excluded from the data analyses. As it may be impossible to distinguish between the combined effects of capture, handling and tagging and the effect of tagging alone, details of capture methods must be provided. It is insufficient to assume that a tag/bm ratio of 2% is appropriate. Although numerous studies have examined tag effects (mainly on salmonids), there remain many avenues for research into the behavioural effects associated with tagging, as well as the role of the environment and fish condition at the time of tagging. Such studies are essential before it is possible to systematise information and state more general recommendations about maximum tag size for different fish species under various conditions.

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