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Post-release survival and feeding in reared turbot

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Abstract

As part of the Danish restocking program, an experiment was carried out with four groups of turbot *Psetta maxima* released on two different occasions at the same location in Århus Bay, Denmark. One objective was to analyse the duration of post-release mortality and the magnitude of this mortality. In 2003 a group called Large turbot (17.1 cm total length (L_T)) and a group called Intermediate (L_T=11.8 cm) were released, and in 2004 two similar-sized groups called Naive and Conditioned (L_T=9.8 cm) were released. The Conditioned differed from the Naive turbot by being transferred to enclosures at the release location six days prior to the actual release. This experiment was performed to investigate whether such a conditioning period had a positive effect on the survival and hence the success of the stocking. All the groups released were monitored daily until day 8, using a juvenile flatfish-trawl to recapture the fish. The catches were analyzed on the basis of a normal distribution approximation method, founded in diffusion theory, from which daily abundance of the released fish and hence post-release mortality could be estimated. The group of Large turbot suffered negligible post-release mortality, but for the Conditioned, Naive and Intermediate groups the loss varied between 34 and 66% d^{-1}. The mortality for the Conditioned group was found to be half that of the Naive turbot released simultaneously. The period of high post-release mortality was estimated to be restricted to three days after release. The only active predators observed in the area were birds. Besides estimating mortality the diffusion model provides an estimate on the catchability of the released turbot when fished with a juvenile flatfish-trawl. Catchabilities varied between 38 and 52% for all releases except for the 17 cm sized turbot released, where catchability was only 12%. The feeding performance of the released fish was also analysed and compared with that of wild fish caught at the same location. These results showed that the proportion of stomachs containing food increased not only with time after release, but also with the size of the turbot. However, whether or not fish was included in the diet was not related to size but to time after release and to whether they had been conditioned or not.

Keywords: Stocking; Post-release mortality; Catchability; Conditioning; Bird predation; Burying behaviour

1. Introduction

As witnessed in other marine ecosystems, several of the most important fish species in the inner Danish waters have been subject to drastic declines during the last decades (Hoffmann, 2000; Munch-Pedersen, 2005). Consequently, severely reduced catches have been observed in both commercial and recreational fisheries. In an attempt to reverse this trend, a Danish fish stocking program was initiated in 1989 to restore fish stocks in both inland and marine waters (Rasmussen and Geertz-Hansen, 2001; Støttrup, 2004). One strategy for marine waters was to examine the potential for stocking through multiple releases of artificially bred juveniles. Turbot *Psetta maxima* was used as a model species and a large-

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scale tagging/recapture program was carried out between 1991 and 1997. The results showed the same mortality and growth in wild and reared turbot, when the post-release period was not taken into account (Støttrup et al., 2002). This research led to the conclusion that restocking flatfish such as turbot through releases is a viable option and that future work should focus on optimizing such releases in terms of finding ideal habitats, reducing the hatchery costs and improving post-release survival of the released individuals.

Recent studies have shown increased mortality of reared turbot just after release, a phenomenon referred to as the post-release mortality (Sparrevohn et al., 2002; Iglesias et al., 2003). Similar results have been reported for stocking experiments with other species, e.g. Japanese flounder *Paralichthys olivaceus* (Furuta et al., 1997) and Atlantic salmon *Salmo salar* (Henderson and Letcher, 2003). A link between post-release mortality and increased vulnerability to predators has been demonstrated in laboratory studies (e.g. Kellison et al., 2000; Hossain et al., 2002; Fairchild and Howell, 2004). This was suggested to be due to a lack in behavioural skills of the reared individuals compared to their wild counterparts. In order to limit the loss during the critical post-release period, it has been proposed that hatchery-reared fish should experience a period of conditioning before release (Howell, 1994; Kellison et al., 2000). Ways of improving natural skills in flatfish can be to introduce them to sediment that resembles the sediment found in their natural environment, either at the hatchery or alternatively keeping the fish encaged and protected from predators in the release area for a period before the actual release. Another option is to rear the fish to a size where they have reached a refuge from most predators (Leber, 1995), a strategy that might not be viable for economic reasons.

Reported post-release mortality rates are high, and if they were to remain at that level for a prolonged period, there would very soon be practically no survivors. On the other hand, results from several tag-recapture studies have shown this could not be the case as recaptures were made up to a number of years after their release (e.g. Leber and Arce, 1996; Støttrup et al., 2002). Therefore, post-release mortality seemed to be restricted to a limited period, and hence not only the intrinsic mortality should be investigated and minimized, but also the length of period during which high post-release mortality rates are observed.

Estimating mortality and growth of released individuals can be expensive and time consuming. Instead, stomach content and proportion of empty stomachs can serve as proxies for how well the released fish have adapted to their new environment. These measurements can easily be obtained and compared to data from wild individuals in the area. For Japanese flounder, one study has shown that feeding behaviour differs between reared and wild individuals, where the latter spend less time off-bottom (Furuta, 1996). Another study has shown that the time spent off-bottom increases with starvation (Miyazaki et al., 2000). So stomach content is not only a direct measurement for the feeding performance of released individuals, but may also indirectly provide information on related behavioural traits that may affect their predation risk.

In the present study, both the duration of the post-release mortality period and its impact on the numbers of individuals surviving were determined for four groups of released turbot. The total length of the fish released ranged from 10 to 17 cm. One group was kept encaged at the release position in order to condition them to the environment before release. These results were compared with a previous study on released turbot at the same location (Sparrevohn et al., 2002). Besides estimating the mortality for each group, stomachs were analyzed in order to establish how size and conditioning affected initial post-release feeding performance.

2. Materials and methods

2.1. Study area

Begtrup Vig (56°10′30 N, 10°28′00 E) is a small bay in the eastern part of Jutland, Denmark. It has a homogenous sandy bottom and limited exposure to the dominant westerly wind, two features that make it suitable as study area.

2.2. Fish and tagging

All turbot released in this experiment came from one commercial hatchery and the same Skagerrak brood stock. The fish were reared in outdoor ponds on natural zooplankton during the larval stage and transferred to indoor tanks after metamorphosis, where they were weaned to a dry diet. Two weeks prior to release, total length (L_T) was measured and each turbot was tagged with an individually identifiable external T-bar tag, obtained from Hallprint, Australia. In 2003, a total of 5000 large-sized turbot (Large; $L_T \pm SD = 17.1 \pm 1.7$ cm) and 5000 intermediate-sized (Intermediate; 11.8 ± 0.9 cm) turbot were released. In 2004, 5000 turbot (9.8 ± 0.9 cm) were divided equally into two groups called Naive and Conditioned. The term ‘conditioning’ in this paper describes the period when the turbot were confined to cages placed in their natural environment. The term ‘naive’ is