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HOW DO REARED TURBOT ADAPT TO THE ENVIRONMENT? II. CONDITION INDICES.

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Abstract

During 1991 and 1992, 8877 and 8049 (size), turbot juveniles were released in the southern area of Kattegat, off the north Seeland coast. The fish were tagged with external Floy-tags prior to release to examine their subsequent growth and migration patterns. These results, together with those from survey samples of stomachs from released and wild fish are reported elsewhere. In this study, the application of condition indices to provide information on the physiological condition of the released and wild fish was examined. Three condition indices were analyzed; hepato-somatic index, fin-somatic index and condition factor, using both wet and dry weight data, for released and wild fish caught during 3 surveys in October 1991, and May and August, 1992. The results obtained are compared to those obtained on the stomach analyses, as well as to indices obtained in a feeding experiment with turbot juveniles fed different rations.

Introduction

An increasing success in the mass rearing of juvenile marine fish has provided an opportunity to examine prospects of stock enhancement of various species. The feasibility of such projects is, in part, related to behavioral aspects of reared fish effecting post-release growth and survival. The adaptation process may be critical; the fish may experience difficulties in the transition to a different food supply, or in avoiding predation. Examples of behavioral, morphological, physiological and biochemical differences were reviewed by Blaxter (1975). More recent studies comparing wild and reared cod, showed short term differences in feeding behaviour (Nordeide & Salvanes 1991) and results from laboratory studies suggested behavioral differences towards a potential prey (Nordeide & Svåsand 1990). In the longer term, comparative studies have revealed no clear differences in migration (Svåsand 1990) or stomach contents (Kristiansen 1987) between wild and reared cod, when recaptured more than 5 months after release in the sea. Few similar studies have been carried out comparing wild and reared flatfish in the natural environment.

Mass releases of reared juvenile turbot are carried out in the southern Kattegat as part of an extensive stock enhancement program with the main aim to determine whether or not stock enhancement of flatfish is feasible in open seas. Biological and behavioral differences between reared and wild turbot are examined. A quantitative index for the evaluation of the nutritional status of the fish was necessary as an supplement to comparisons of feeding behaviour based on stomach contents. In an experimental study on turbot juveniles, various indices were compared to examine which was the most sensitive to different feed rations applied (Hvingel & Støttrup 1 in prep.). These indices were then applied to field data to examine and compare their applicability as well as to compare the physiological condition of the released and wild fish. The results of this work are presented in this paper.

During this study, a comparison of prey preferences, growth and migration between reared and wild turbot has also been conducted (Hvingel & Støttrup 2 in prep.).

Materials and methods

Released fish
Between 8000 and 9000 turbot juveniles (size) were released each year in the spring of 1991 and 1992 (see Table 1). The turbot were individually tagged with external Floy FD-67 anchor tags before being released in southern Kattegat. The tagging and release is described in Hvingel and Støttrup (2, in prep.).

Recaptures
In addition, 3 surveys were carried during October 1991, May 1992 and August 1992 respectively, using sole or salmon nets. The nets were set around sunset and collected 1 hour after sunrise. They were placed on ice on board the fishing vessel and frozen (-18°C) on arrival at the local fishing harbour.

In the laboratory, the fish were thawed, measured for total length to the nearest scm and weighed to the nearest g. The fish were then dissected to remove the liver and fins as described in Hvingel & Støttrup, (1, in prep.). The following parameters were estimated:

Hepato-somatic index **HSI** = (liver weight/total body weight) * 100
Fin-somatic index **FSI** = (fin weight/total body weight) * 100
Condition factor **CF** = (total body weight/length^b) * 100, where b was estimated to be 3 from the slope of the lnW/lnL-plot.
Specific growth rate **SGR** for released fish = $((\ln W_2 - \ln W_1)/(t_2-t_1)) * 100$, where $\ln W_1$ and $\ln W_2$ are the length at release (t_1) and recapture (t_2).

Length and weight units are cm and g respectively. The letters "**D**" and "**W**" appended to the conditions indices indicate estimations based on dry or wet weight respectively.

Table 1. Number of turbot juveniles released during 1991 and 1992, size at the time of release and larval-rearing method applied.

Number tagged	Date released	Length (cm±SD)	Larval rearing method	Recaptures numbers and % 1991 surveys	1991 fisher-men	1992 surveys	1992 fisher-men
3099	07.05.91	12±1	extensive	10	30	2	48
5000	08.08.91	11±1	intensive	1	7	16	133
8094	01.05.92	12±3	extensive			8	81
Recaptured fish, tag lost		(1991 releases)		12		2	
		(1992 releases)				29	

Results

The fish were caught in depths of 2-5 m along north Seeland's sandy coastline, inshore of the release site (within area oulined by top right box, Fig. 1). A total of 108 wild and 80 released fish were caught during the 3 surveys conducted. The size distribution of released and wild turbot ranged from 8 - 23 cm and 11 - 25 cm respectively (Fig. 2) and encompass recaptures of group-0 and group-I turbot, 2-15 months after release.

The water content in the released turbot was significantly higher at all times in the liver, fins and fillets examined as compared to that in wild turbot (Figs. 3a - 3c).

Liver water content was 3-7% higher in reared turbot ($P<0.001$; two way-ANOVA), and represent a noticeable increase from 72% at release to 77-80% at recapture. A significant increase in liver water content with time in released turbot was evident with time ($P=0.009$; one way-ANOVA). On the other hand, differences in water content with time in wild fish were significant only between May and August ($P<0.001$;Tukey HSD). A slight (non-significant) decrease was observed from October to May.

Fin water content remained unchanged with time in released turbot, and these contained 1.5-

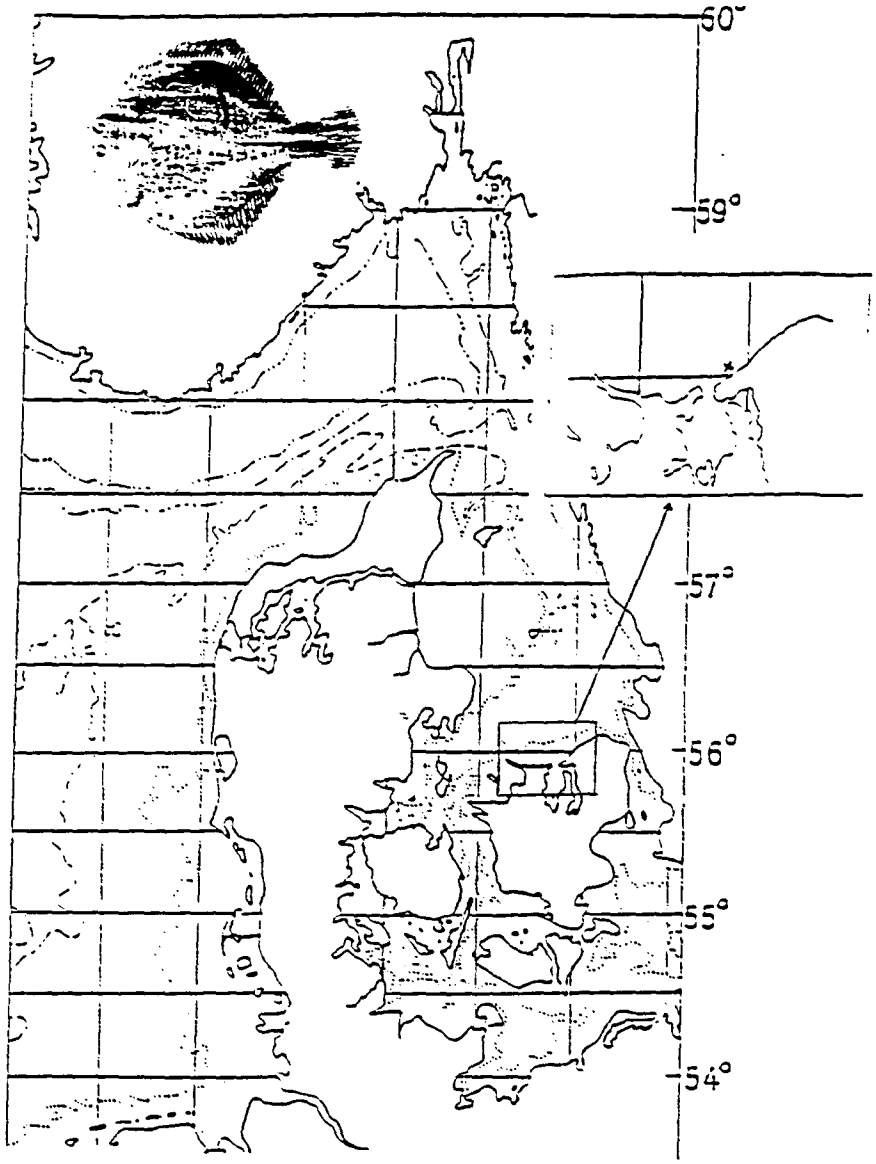

Fig. 1. Site of release (upper right box) of reared, tagged turbot (upper left box), released off the north Seeland coast (Southern Kattegat) during 1991 and 1992.

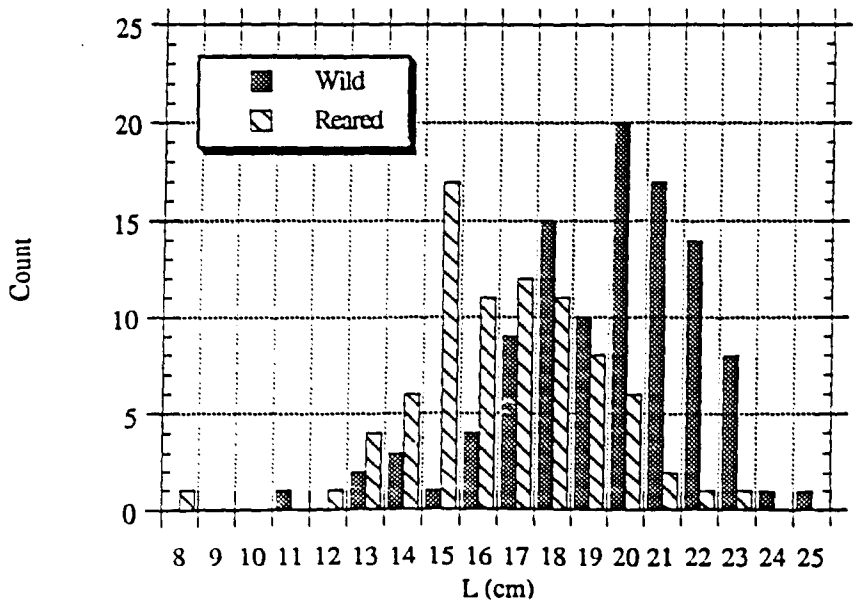

Fig. 2. Length distribution of released (reared) and wild fish caught in the Southern Kattegat during Oct. 1991, May 1992 and Aug. 1992.

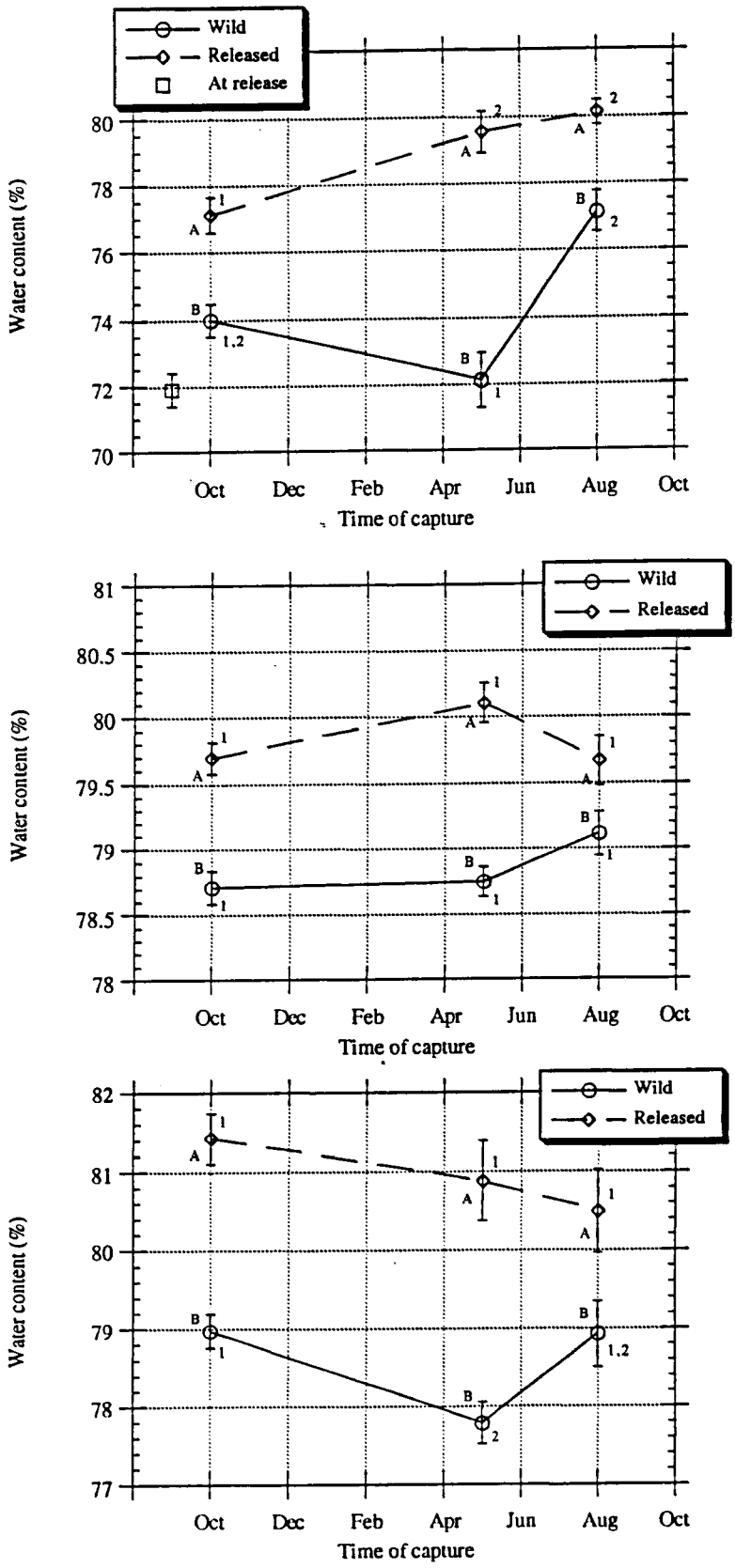

Fig. 3 a,b,c. Mean water content (%)±S.E. of livers, fins and fillets from wild and released turbot sampled in the Southern Kattegat Oct. 1991, May 1992 and Aug. 1992. Different letters indicate a significant difference between wild and released means at the particular sampling time (one way-ANOVA; $P<0.05$) and different numbers indicate a significant difference between means at different sampling times (Tukeys HSD-test; $P<0.05$).

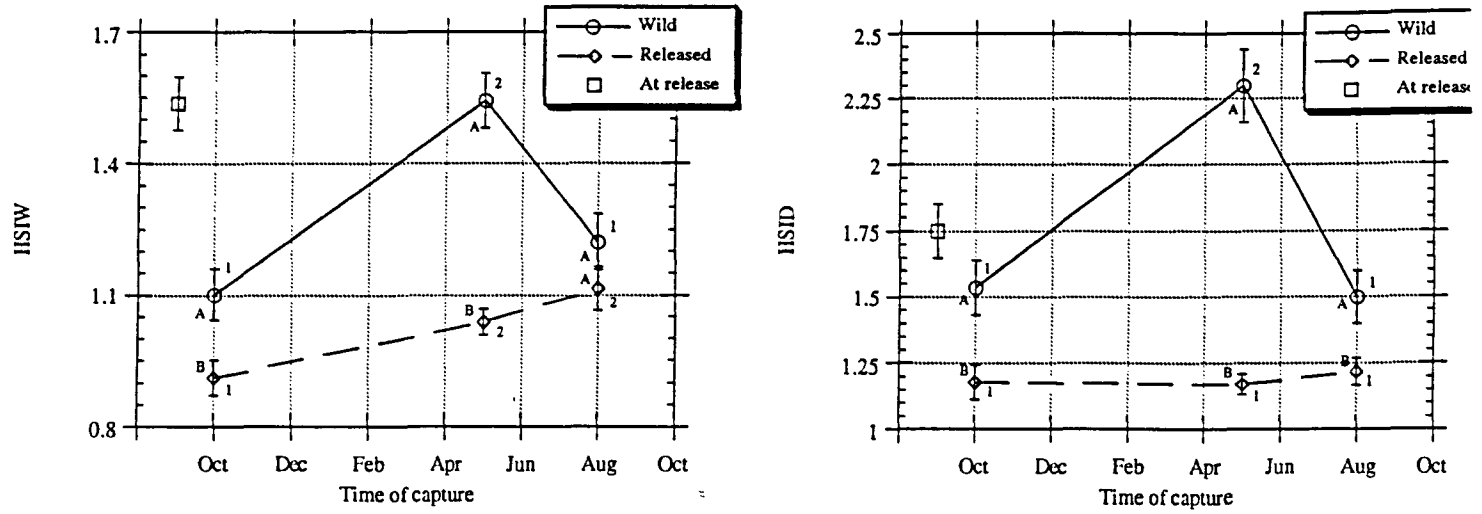

Fig. 4 a,b. Mean hepato-somatic index, wet and dry ± S.E. of wild an released turbot sampled in the Southern Kattegat Oct. 1991, May 1992 and Aug. 1992. Different letters indicate a significant difference between wild and released means at the particular sampling time (one way-ANOVA; $P<0.05$) and different numbers indicate a significant difference between means at different sampling times (Tukeys HSD-test; $P<0.05$).

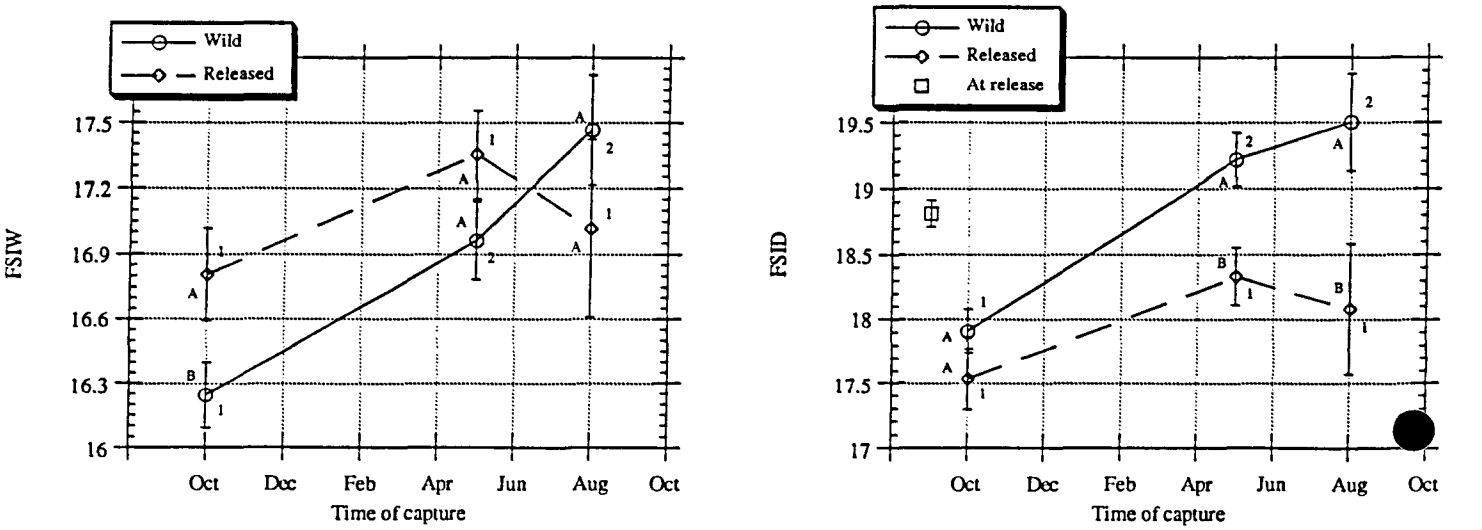

Fig. 5 a,b. Mean fin-somatic index, wet and dry ± S.E. of wild an released turbot sampled in the Southern Kattegat Oct. 1991, May 1992 and Aug. 1992. Different letters indicate a significant difference between wild and released means at the particular sampling time (one way-ANOVA; $P<0.05$) and different numbers indicate a significant difference between means at different sampling times (Tukeys HSD-test; $P<0.05$). Value at release: FSIW = 25.4 ± 0.2.

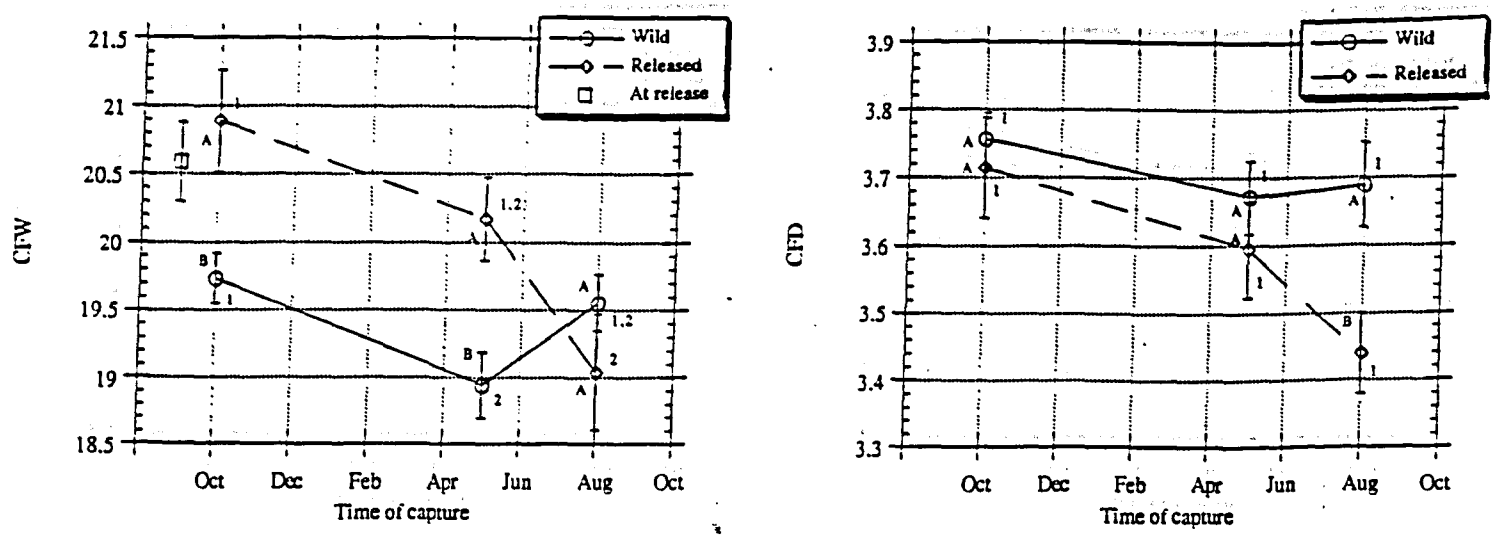

Fig. 6 a.b. Mean condition factor, wet and dry $\pm$ S.E. of wild an released turbot sampled in the Southern Kattegat Oct. 1991, May 1992 and Aug. 1992. Different letters indicate a significant difference between wild and released means at the particular sampling time (one way-ANOVA; $P<0.05$) and different numbers indicate a significant difference between means at different sampling times (Tukeys HSD-test; $P<0.05$). Value at release: CFD=4.54$\pm$0.08.

2.5% higher water content than the wild turbot fins. Increase in fin water content from time of release to time of recapture was more than 10%, whereas water content in wild turbot showed a similar development as in the livers.

In the fillets, water content in the released turbot was 0.6-1.3% higher than in the wild ($P<0.001$; two way ANOVA), and represents an increase of 2-3% from the time of release. There were no significant changes in fillet water content with time in either wild or released fish.

All 3 dry-based condition indices and HSIW were in the wild turbot were significantly higher than those in the released turbot irrespective of time of capture (Fig. 4a, 4b, 5b and 6b). The hepato-somatic index in wild turbot varied according to time of capture ($P=0.008$; one way-ANOVA) with a maximum in May while LSID of the released turbot remained constant at all 3 recapture periods. Seasonal dependence was shown for LSIW in released fish but this was much less evident than for wild fish.

FSIW in released turbot was significantly higher in October, slightly higher in May and lower in August than in wild turbot (Fig. 5a). In the released turbot no changes in the FSI was found ($P>0.049$), in contrast to that in wild turbot ($P=<0.001$;on way ANOVA). Seasonal variation in FSI was similar in wild and released fish.

CFW showed a similar pattern to FSIW, whereas CFD was consistently lower at the 3 capture periods (Fig. 6a and b). Consequently, CFW was significantly higher in released fish ($P=0.049$; two way-ANOVA) and CFD significantly lower ($P=0.022$). No change in CFD was observed in either the wild or the released fish.

Discussion

The wild fish caught in the surveys were slightly larger than the recaptured turbot (Fig. 2) at all recapture periods. It was established from an experimental study examining the relationship between various condition indices and ration, that within a narrow size-range the indices were independent of body size (except FSIW) (Hvingel & Støttrup 1 in prep.). In nature, however, size is associated with several parameters affecting the nutritional status of the fish such as, size-related food selection and predator-prey interactions, habitat selection and maturity induced migration patterns. Also other factors influencing the condition of fish may be size-related such as stress and resistance to disease and parasites. However, although the results were corrected for length differences in a 3-way variance analysis, with length as the co-variable, it was evident in all the indices examined that released turbot had a significantly lower condition index than their wild counterparts. Only CFD was no longer significant for reasons which are explained below.

The water content of all 3 fractions was significantly higher in the reared fish as compared to wild. As this difference could not be assigned to a high water content at release, this indicates a poorer post-release nutritional condition. This relatively poor condition of the released fish was not a result of a low condition at release; on the contrary, reared fish are normally characterised by a good condition which may well have been higher than that of wild turbot at the time of release. Considering this nutritional advantage, the large difference in nutritional status between wild and reared fish is even more remarkable. Another implication of the large differences in water content is that the reliability of the wet-weight-based condition indices is more dubious.

It was clear from the above-mentioned experiment (Hvingel & Støttrup 1 in prep.), that "Fulton's condition factor (CFW) could only be used in comparisons of populations if their water content could be considered equal. In that study, CFW did not reflect true differences in stored energy and this index was shown to be the least sensitive to varying growth rates probably because there was no discrimination between the weight of water and the weight of energy reserves. Furthermore, the use of the condition factor to compare populations may be complicated by differences in anatomy. Anatomical differences in turbot related to different habitats was earlier observed by Kändler (1949) and anatomical differences related to different rearing strategies have also been observed (personal observations). Thus, the higher CFW values obtained for released turbot did not indicate a better nutritional status, as indicated by CFD, where the values for released turbot were significantly lower than for wild turbot.

The wet-based form of the most sensitive indicator of condition, the hepato-somatic index, was not sufficiently affected by differences in water content to mask differences in the condition of wild turbot. This index, together with HSID, indicates a significantly lower condition of released fish.

The results from the stomach analyses carried out on the same fish (Hvingel & Støttrup 2 in prep.) showed no differences in stomach contents between wild and released fish even in the fish caught just 2 months after release. These results on turbot and those obtained by Svåsand & Kristiansen (1985) and Nordeide & Salvanes (1991) on cod, suggest that released, reared fish may require an adjustment period of shorter or longer duration where they largely feed on non-evasive prey. Once adjusted, feed selection resembles that of their wild counterparts. Comparing these qualitative results with the results obtained on the condition indices in this study, suggests that the indices may be a more sensitive measure for post-release adaptation

than comparison of qualitative stomach analyses.

In this study, it could not be excluded that the tag in itself was stressful to the fish and ultimately the cause of a poorer nutritional status, even up to 1½ years after release. Turbot juveniles are "ambush hunters" relying on a good camouflage for success (Keenleyside 1979). Normally, they bury themselves in the sand, and together with their pigmentation become almost invisible while waiting for a suitable prey to come into the attack radius. In a failed attempt, turbot rarely pursue their subject for any prolonged period. If the camouflaged turbot no longer has the same degree of surprise in its attack, it will experience more difficulty in capturing evasive prey. It may then change its feeding strategy to smaller prey, decreasing its "cost-benefit ratio" (Townsend & Winfield 1985; Hart 1986). Thus, the orange tag may have reduced the turbots camouflage, possibly effecting its feeding success and resulting in a poorer condition in the released (tagged) fish as compared to their wild counterparts.

Furthermore, the tag may have enhanced the turbot's vulnerability to predation. Other fish may attack the tag believing it to be prey, a further stress for the released fish. One further negative aspect arising from the use of external tags, was the tendency for blue mussels (Mytilus edulis) and algae to attach and grow on the tag, rending it more cumbersome than otherwise. Further studies, using internal chemical markers are intended to examine whether or not the external tags are the sole cause for the poorer performance of the released fish.

The results from this experiment suggest FSID and FSIW may be appropriate indices for comparing the nutritional status of wild and post-release, reared turbot. The released fish had a significantly lower conditional status than the wild turbot even after 1½ years post-release. Another observation also supporting this evidence was the lack of seasonal response in the condition indices in released fish as compare to the wild turbot. Although the released fish may not have been as efficient hunters or feeding on smaller items as compared to their wild counterparts, a relative increase in the indices similar to that observed for wild turbot, was expected during the summer months as a result of a larger food supply. Possibly, the food intake was insufficient to meet the increasing metabolic demands during the higher summer temperatures and thus, the released fish failed to take advantage of the increase in food supply to build up energy stores.

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