FISHERIES R&D FINAL PROJECT REPORT

1. **Project Code: MF04 14**

2. **Title: Effects of UV-B on planktonic eggs and larvae of marine fish**

3. **Commenced: 4/93**

4. **STA Planned Completion date: 3/96**

5. **Actual Completion date: 3/96**

6. **Results:**

The research programme was directed towards establishing factual information on the potential effects of enhanced solar middle-ultraviolet radiation (UV-B), resulting from atmospheric ozone depletion, on the early life history stages of fish. The results will improve the quality of advice available on the effects of a change in one of the environmental factors that could affect fish stocks.

The work began with a detailed review of relevant published literature of incident solar UV-B levels, their penetration of sea water and the probable effects of predicted ozone depletion. Information obtained enabled estimates of penetration of UV-B through sea water to be made, together with measurements of current incident UV-B levels and seasonal changes. Spectral measurements were also made locally to confirm the validity of these findings. Incident UV-B radiation is absorbed in sea water largely by dissolved organic substances derived from terrestrial run-off and it is scattered by suspended solids where turbidity is high. In general, therefore, penetration of UV-B is greater further offshore than in coastal waters. It is estimated that up to 25% of incident UV-B radiation could penetrate to a depth of about 1m in shelf seas, whereas in clearer oceanic water, 25% of the surface level would be measured at a depth of about 5 m. Seasonal changes in day length and solar elevation affect the daily dose of solar UV radiation received at the sea surface. Natural sunlight in mid May, for example, (the natural peak of larval sole abundance) would give a daily UV-B dose of about 1.0 $kJ_{bio. eff.}$ m^{-2} (the energy unit weighted for the effective biological damage it can cause to genetic material) and with 15% ozone depletion, it would be expected to rise to 1.5 $kJ_{bio. eff.}$ m^{-2}. In mid-June the comparable figures would be about 1.5 and 2.5 $kJ_{bio. eff.}$ m^{-2} respectively.

A review of the literature on the effects of UV-B in the marine environment was also undertaken and a bibliography was prepared. Approximately a third of the references deal with results of laboratory experiments with planktonic organisms and fish. Much of the rest of the material gives general predictions on the effects of ozone depletion, but little has been published that can be specifically related to fisheries.

The reviews allowed a rapid and effective experimental assessment of the effects of UV-B on eggs and larvae of selected commercially important fish species to be undertaken. Experiments were carried out with yolk-sac larvae of Dover sole (*Solea solea*) and turbot (*Scophthalmus maximus*), which were exposed to various levels of simulated solar ultraviolet radiation during the five day period of yolk resorption. Eggs of cod (*Gadus morhua*) were subjected to similar treatment during ten days before hatching. The light spectrum used was enhanced with short wave (< 290-300 nm) UV-B to provide suitable treatment levels that would simulate forecast solar UV-B radiation after 15-20% ozone depletion. The required treatment doses were calculated to allow for the different energies in the artificial ultraviolet spectrum compared with natural sunlight. For comparative purposes, the three species were exposed to a similar range of doses. They were estimated to be biologically equivalent to those expected in the surface metre of moderately productive shelf waters, such as the Irish Sea, at the time at which the species normally spawn. A study of the effects of lower intensities was also carried out for sole.

Growth of sole yolk-sac larvae was affected by the dose of UV-B received. The mean length at the end of the yolk-sac stage decreased with increasing dose. The relationship appeared to be linear and extended to relatively low levels of UV-B. Larvae were on average between 1 and 2% shorter than normal at the time when they would begin to search for prey, after exposure to a dose equivalent to the forecast increase in UV-B due to ozone depletion.

Mortality rates appeared unaffected by the UV-B irradiance within the range used, and there were no gross abnormalities in the histology of the skin or eye. The success with which larvae from the different treatments captured live prey at the time of first feeding was also assessed, but the results from these experiments were inconclusive. Samples of treated larvae were reared for a few weeks in the absence of UV-B, but growth and appearance of the juvenile fish did not seem to be affected at this stage. Unlike sole, there was no effect of UV-B on the growth of turbot larvae. Even with the maximum dose of UV used, which was equivalent to that received in midsummer, there were no differences in the mean size of turbot larvae from the different treatments at the end of the yolk-sac stage. Light microscopic examination of skin and eyes did not reveal differences either.

Cod has a rather more prolonged period of embryo development than sole and turbot. Larvae are more advanced when they hatch, with pigmented eyes and only sufficient yolk for 2 or 3 days. Exposure of cod eggs to a range of doses of UV-B similar to those used for the other species did not appear to affect embryo development, or mortality before hatching. However, mortality immediately after hatching was over 80% greater than the control group (no UV-B) in those treatments that had been subjected to the highest UV doses. The lowest treatment dose, which was equivalent to sunlight in March, was associated with about 10% more mortality than in the absence of UV-B.

Although the data obtained is limited to eggs and early larval stages, it allows some assumptions to be made about the relative significance of the forecast increase in natural UV-B levels for recruitment of fish stocks. Growth rate is considered to be an important factor in the determination of survival of larval fish. Larger larvae tend to swim faster than small ones and are therefore better able to capture prey and escape predation. It is clear that enhanced UV-B can reduce larval growth rate of some species of marine fish in an experimental situation, and this therefore could disadvantage them in the natural environment. However, because of the complexity of predicting the extent of UV-B penetration in areas where planktonic eggs and larvae are present, it is difficult to be certain of the degree of these effects in natural populations. In general, in moderately productive waters, any effects will be restricted to the community in the first metre below the surface and if they are limited to causing small variation in growth rate, the impact on recruitment is unlikely to be great. Nevertheless, if there were longer term effects that could influence survival or reproduction, they would have considerably greater impact on recruitment processes than the effect on growth. Sole yolk-sac larvae, for example, are small, translucent, and relatively lightly pigmented. Penetration of UV-B into body tissues must occur since an effect on growth is one indication that short-term, sub-lethal tissue damage has been caused. Damage to genetic material of the germ cells of the gonad primordia, which would affect long-term reproductive performance may also occur, but further work is required to identify whether it does.

The difference between species in their tolerance of UV-B is relevant to species biodiversity. Plainly, species have evolved to be adapted to the UV characteristics of the particular environment in which they are found. The lack of sensitivity of turbot larvae is consistent with their summer spawning period and a presence in the hyponeuston (living right at the surface of the sea). They are naturally more pigmented than sole, and the pigment and perhaps specific enzyme systems probably offer some protection from UV. Cod normally spawn in February and March when UV levels are low, and the developing embryo seems to have very little protection against the effects of UV. Sole, which spawn later in the spring appear to have intermediate sensitivity. It is likely, therefore, that the impact of ozone depletion will be most significant for species which spawn early in the year, both because of their greater sensitivity and because the proportional increase in UV-B radiation is at its greatest in early spring.

7. Targets and Output:

Targets have been met as outlined in Section 6. The only proviso is that preparation of full scientific accounts of the results is still proceeding although they are in draft form.

8. Overall conclusions:

This project has contributed to the evaluation of the significance of ozone depletion to fish stocks by the experimental assessment of direct effects of an enhanced UV-B spectrum to fish larvae. The results clearly demonstrate that the early life history stages of fish are vulnerable to UV-B irradiation, and that the extent of this may depend on the particular environment to which they are adapted. Those species that are normally exposed to the highest UV-B levels (eg turbot, the larvae of which are at the sea surface in June) appear to be well protected, whereas those that are not normally exposed to high levels of radiation (eg cod and sole, which are spread over greater depths in March and May respectively) appear to be more vulnerable. The reduction of the growth rate of larval fish in the sea caused by UV-B may contribute to increased mortality from predation and so affect the number of larvae surviving to metamorphosis, although this may have a marginal influence on recruitment. Any long term effects on development and reproduction are likely to be more significant.

9. Uptake and implementation:

Information and advice has been provided to HQ (SWIF, EFIS) with respect to the effects of forecast changes in solar UV-B. This will enable more accurate advice to be provided on factors affecting recruitment of commercial fish in the context of the management of stocks.

Information describing results of the experimental work has been put on general release through the DFR Handout series.

10. Further work:

Potentially, effects of UV-B on the unpigmented cells in developing eggs may be of more significance for long-term growth and survival than the effects demonstrated in yolk-sac larvae. In addition, there is evidence that synergistic effects of UV-B and some chemical pollutants, such as polycyclic aromatic hydrocarbons, can lead to a greater impact on egg and larval development than either individual factor. Both these subject areas should be addressed in future proposals.

A project proposal entitled: *Long term effects of UV-B on the development of marine fish* was submitted to the MF Commission in 1995, but was not accepted.

A proposal on the synergistic effects of UV-B and chemical pollutants will be submitted for consideration for the AE Commission in 1996.

11. List of Publications:

DFR Handout No 36: *UV-B and Fisheries.*

In preparation:

Effect of simulated solar UV-B on the growth of sole *Solea solea* (L.) yolk-sac larvae.

Effect of simulated solar UV-B on the growth of turbot *Scophthalmus maximus* L. yolk-sac larvae.