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Possible Approaches for Co-operative Pacific Salmon Research

by

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ABSTRACT

As climate changes over the next few decades, stewarding the aquatic resources of the North Pacific Ocean through what may prove to be the most difficult period in the history of fisheries management will require effective scientific cooperation at an international level. We must deal with processes that accelerate learning and address the importance of decision making at high levels of uncertainty. This document is submitted to NPAFC to initiate discussion on possible topics for cooperative international research on Pacific salmon.

INTRODUCTION

As climate changes over the next few decades, stewarding the aquatic resources of the North Pacific Ocean through what may be the most difficult period in the history of fisheries management will require effective scientific cooperation at an international level. We must deal with processes that accelerate learning and address the importance of decision making at high levels of uncertainty.

It is our belief that in order to get the best information quickly to all countries we need to have teams of experts address sharply focussed questions or issues. These questions must be well-defined. They must permit a highly co-ordinated international research effort, and they must establish the credibility of such collaborative efforts to *successfully* provide needed information. The teams would have a clear time frame within which to obtain as much information as possible using existing published and unpublished data, as well as carrying out original scientific studies where needed.

We propose that we begin the program with a co-ordinated study on selected aspects of the behaviour, biology, and dynamics of Pacific salmon throughout their ocean range. This study, focussed on a single year of intensive field research, could be called the "International Year of the Salmon," and would involve all salmon producing countries. During the field research, information would be collected on the effect of physical factors on the distribution and migration of salmon in response to physical factors, and the effect of interaction between species on their diets, growth, and survival. By focussing on salmon it should be possible to capture the interest of both funding agencies and the public in a way that would be difficult to do for other marine species. The scientific thrust of such a program would be to directly address the effects of climate change and carrying capacity on salmon within clearly defined operational goals.

An "International Year of the Salmon" will attract world attention to the importance of protecting salmon and the relevance of all areas of scientific research in the North Pacific Ocean to sustaining our fisheries, to the predicted consequences of climate change for our fisheries, and for the need to reduce atmospheric emissions and other documented man-made impacts on salmon. We expect that pursuing such a program will lead to an international monitoring network, and an ongoing exchange of data and related discussions. A continuous exchange of data can be used to test and fine tune climate model predictions and alert legislators to possible changes to wild and enhanced salmon stocks. The program will also bring researchers together, providing a forum to identify the key issues requiring further attention

A PROPOSAL

Detecting the effects of climate change on fish populations and adapting to the effects of those changes may require new opportunistic approaches to research. Biologists expect that whole ecosystems will be affected by climate change.

However, we now have some clear ideas about what changes in ocean climate may bring about for Pacific salmon. On shorter time scales, the intensification of the Aleutian Low since 1977 has been accompanied by substantially higher salmon population levels (Beamish and Boullion 1993), but the precise mechanisms leading to higher production are unclear, as are the periods within the extensive marine life history phase when they operate. If ocean climate should change states again, for which there is already some evidence, very severe disruptions to coastal fisheries will result.

On longer time frames, the level of ocean warming predicted to occur by the current generation of General Circulation Models is sufficient to exclude Pacific salmon from the entire North Pacific Ocean in winter. The response of salmon abundance to ocean temperature is shown in Fig. 1, which is based on data collected during a co-operative research program between Japan and Canada.

The results from this joint research demonstrate that the primary response of salmon abundance in the open North Pacific is to temperature, and that salmon show an extremely sharp decline in abundance over a very short temperature interval-- typically two orders of magnitude in ±0.4°C. Fig. 2 is a summary graph showing the thermal limits by season; the roll-off in abundance with temperature in the other seasons is essentially as sharp as it is for the summer results shown in Fig. 1.

The current generation of General Circulation Models (GCMs) predict increases in sea surface temperatures of 2°-3°C in the North Pacific following a doubling of atmospheric CO_2 levels, with geographic and seasonal variation from this average. The level of ocean warming predicted by the Canadian Climate Centre's coupled ocean-atmosphere GCM falls in the mid-range of the predictions currently available.

Predictions about future climate suggest that ocean warming is likely to substantially reduce the amount of the North Pacific available for grazing and growth in summer (Fig. 3A) and entirely exclude salmon from the North Pacific Ocean in winter (Fig. 3B). The upper panel shows that the amount of suitable thermal habitat available in the North Pacific Ocean is predicted to decline to about half its present area when CO_2 levels in the atmosphere double (about 2070 A.D.). However, under current predictions about global warming the ocean range in ***winter*** is predicted to disappear completely for about three months of the year. The precise effects of such changes on ocean carrying capacity on salmon are unclear, but clearly indicate the need for further joint study.

Relation to GLOBEC and other Research Programs

Both U.S. and Canadian GLOBEC science plans (GLOBEC Canada 1994; U.S. GLOBEC 1994) emphasize the themes that:

(1) coupling between physical and spatial processes and their resulting spatial and temporal patterns is strong in the ocean, and

(2) data collection and analysis should be at the level of "large marine ecosystems" with identifiable properties, because of the utility of these physical units (Sherman and Alexander 1986).

A project focussed on the interactions of salmon with their ocean environment would fit very well within this framework. We now have a general framework where the large scale effects of thermal climate on salmon distribution are known. Ocean-atmosphere thermal linkages are already under study, and there are also resolutions from both PICES and the North Pacific Anadromous Fish Commission (NPAFC) that the response of salmon populations in terms of growth rate, maturity, and survival should be studied.

Our proposal is also similar in thrust to another program that is to focus more on freshwater impacts on salmon. The "Wild Salmonid Watch" (Maitland et al. 1981; Regier and Meisner 1990) has as its objectives to foster conservation, preservation and rehabilitation of distinct species and stocks, genetic resources, diversity of taxa, and to ensure the existence of sufficient and appropriate habitat.

Developing A Science Plan

We propose that specific activities be identified by a small planning team. The team will propose a set of co-ordinated activities that include comprehensive physical and biological studies in both coastal and high seas areas of the North Pacific. For example, Canada would be interested in establishing whether or not it is the oceans or the freshwater habitat that is the primary limitation on salmon production.

As a second example, because the abundance of each species is made up of literally thousands of stocks, evolutionary selection has clearly acted to make all stocks respond at the same temperatures in the ocean-- otherwise the declines in abundance with temperature discussed in the previous section would not be as sharp as they are. But why should evolutionary selection have been as sharp as it appears to be? What are the consequences of changes in ocean climate and salmon abundance for future levels of salmon productivity? Sharp behavioural responses can only be selected for if they have a strong influence on genetic fitness. And, as the factors influencing fitness also directly influence *population productivity* (Charlesworth 1980), it is possible to predict with considerable confidence that changes in the thermal climate of the oceans should have a large impact on salmon productivity.

These are the types of focussed questions that we believe the planning team could use as a basis for drafting specific activities. However, the final determination of what questions should be addressed in an International Year of the Salmon and what measurements should be made would be left to the co-ordinating committee.

CONCLUSIONS

An "International Year of the Salmon" field program could be planned for 1996, a year that may see the start of low salmon returns because of recent changes in the intensity of the Aleutian Low. It would take all of 1995 to plan and coordinate the sampling and monitoring programs and it would take most of 1997 to analyze and report on the results. In science, important discoveries can be made by being in the right place at the right time. We think the place to be for Pacific salmon is in the "International Year of the Salmon" project in 1996.

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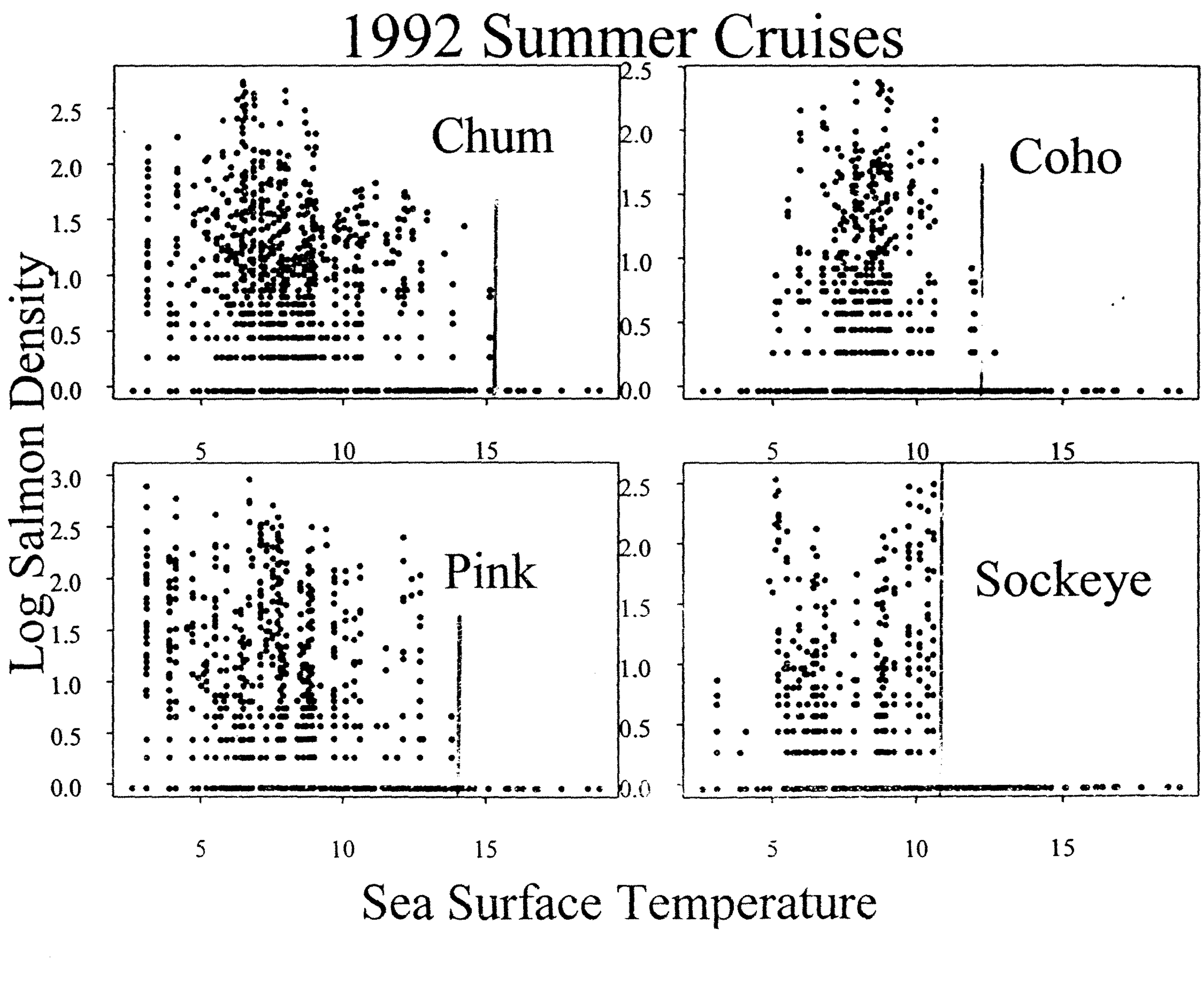

Figure 1. Comparison of log(salmon) abundance vs. sea surface temperature for summer cruises of the 1992 Japan-Canada co-operative research program. Note the very sharp upper thermal limit evident for all four species, and the difference in temperature at which this thermal limit is expressed.

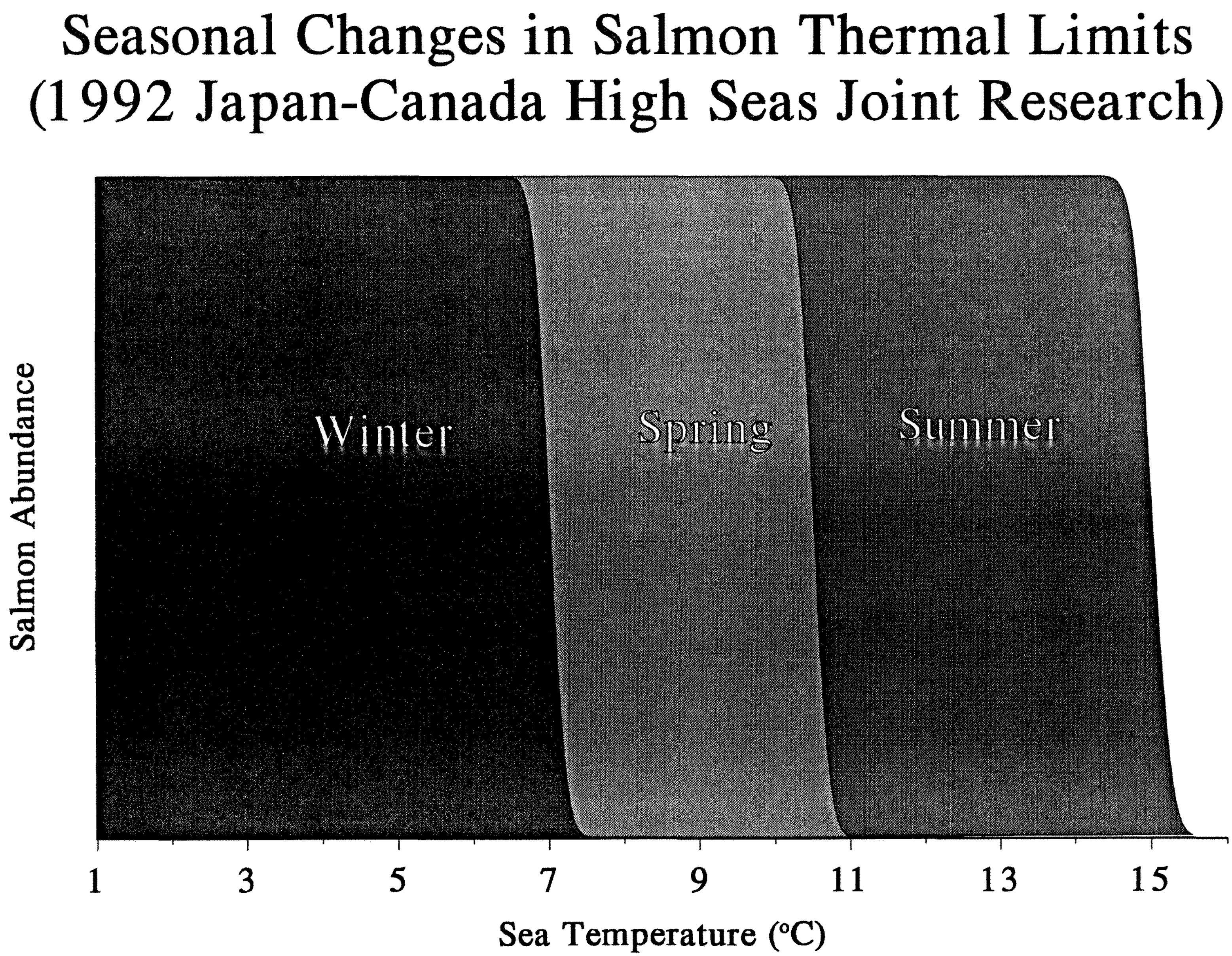

Figure 2. Maximum thermal limit found by season.

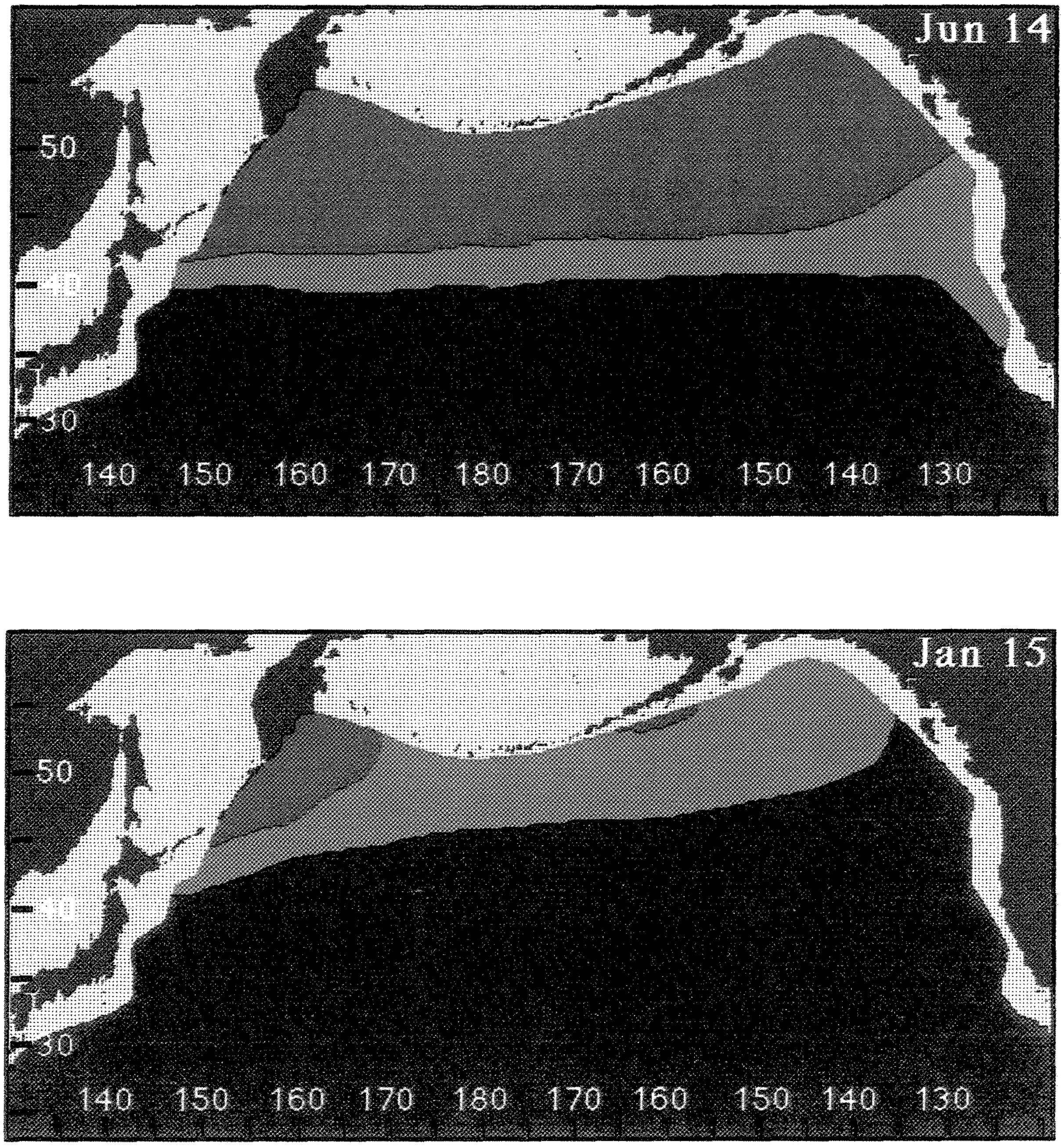

Fig. 3 Predicted position of the southern boundary of the Pacific salmon distribution in summer and winter under present (green) and future (red) climates. Canadian salmon are distributed almost exclusively in the Gulf of Alaska. At current rates of input, the concentration of CO_2 in the atmosphere will double by 2070 A.D. The Canadian Climate Center's coupled ocean-atmosphere general circulation model (GCM) was used to make the predictions of ocean temperature defining the limits to the salmon distribution. All current GCMs predict similar levels of warming. A complete loss of winter salmon habitat is predicted to occur under a $2xCO_2$ climate for three months of the year (October-mid January). Suitable thermal habitat only re-appears after mid-January (lower panel). The area of suitable thermal habitat in summer is also predicted to be much restricted (upper panel).