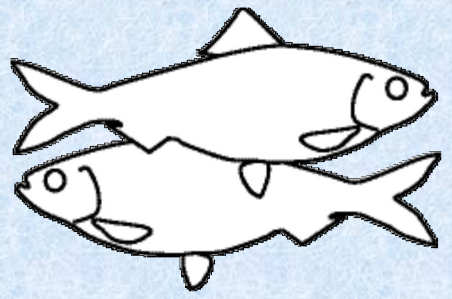

Diadromous Species Response to Climate Change:

A Brief Literature Review Highlighting the Impacts of Climate Change on Diadromous Fish

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The Diadromous Species Restoration Research Network is a five-year initiative funded by the National Science Foundation to advance the science of diadromous fish restoration and promote state-of-the-art scientific approaches to multiple-species restoration through workshops, conferences, web sharing, and journal publications. The Network is a joint project of the University of Southern Maine and the University of Maine's Senator George J. Mitchell Center for Environmental & Watershed Research. This poster presents a literature review exploring the impacts of climate change on diadromous species.

Effects of Climate Change on Fish Habitat

Rivers and Streams:
- Ice-out earlier in year
- Earlier peak spring flow
- Increased frequency of high-flow events
- Earlier low-flow period with a longer duration

Estuarine:
- Increase in tidal volume and exchange
- Inland saltwater penetration extended further
- Decreased overall salinity
- Increase in storm frequency

Marine:
- Sea level rise due to elevated temperatures
- Changes to ocean current thermal and nutrient regimes
- Loss of intermediate "thermal habitat" of 5-15°C
- Increased frequency and intensity of climate processes such as El Nino
- Changes to phytoplankton productivity patterns

Major Effects of Climate Change on Diadromous Fish:

- Poleward shift in suitable habitat, loss of southern portion of species ranges
- Species-specific response to habitat suitability change leading to discontinuity of food webs, creates novel species pools
- Alterations to spawning and migration timings
- Longer growing season
- Increased exposure to invasive species, disease and algal blooms
- Pressure on fish recruitment with habitat loss
- Uncertain impact on commercial harvesting and bycatch

Source: UN: FAO

EXAMPLES OF CLIMATE IMPACT PATHWAYS ON FISHERIES

TYPE OF CHANGES	CLIMATIC VARIABLE	IMPACTS	POTENTIAL OUTCOMES FOR FISHERIES
Fish stocks	higher water temperatures changes in ocean currents	- changes in sex ratios - altered time of spawning - altered time of migrations - altered time of peak abundance	possible impacts on timing and levels of *productivity* across marine and fresh-water systems
		- increased invasive species, diseases and algal blooms	reduced *production* of target species in marine and fresh water systems
		- affects fish recruitment success	abundance of juvenile fish affected and therefore *production* in marine and fresh water

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•Reist, J. D., F. J. Wrona, et al. (2006). General effects of climate change on Arctic fishes and fish populations. Ambio 35(7): 370-380.
•FAO. (2008). Climate change for fisheries and aquaculture. Technical background document, FAO Rome.
•Schweiger, O., J. Settele, et al. (2008). Climate change can cause spatial mismatch of trophically interacting species. Ecology 89(12): 3472-3479.
•Lassalle, G. & E. Rochard (2009). Impact of twenty-first century climate change on diadromous fish spread over Europe, North Africa and the Middle East. Global Change Biology 15(5): 1072-1089.
•Graham, C. T. and C. Harrod (2009). Implications of climate change for the fishes of the British Isles. Journal of Fish Biology 74(6): 1143-1205.
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•Nye, J. A., J. S. Link, et al. (2009). Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. Marine Ecology Progress Series 393: 111-129.
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Management Decision Making Considerations

- ***Increase Resilience of Communities***
  - Restoring habitat in a way that increases fish productivity and acts as a strong carbon sink
  - Create a comprehensive restoration plan that accounts for biotic and abiotic factors for population growth
- ***Long Term Adaptation Planning***
  - Raise awareness of climate change impacts to shape unified, international policies
  - Begin to mitigate the causes of climate change
- ***Improved Fisheries Management***
  - Manage for genetic diversity and tolerant phenotypes
  - Support initiatives to reduce overexploitation of fisheries

•Lassalle, G., M. Beguer, et al. (2008). Diadromous fish conservation plans need to consider global warming issues: An approach using biogeographical models. Biological Conservation **141(4): 1105-1118.**
•Lassalle, G., M. Beguer, et al. (2009). Learning from the Past to Predict the Future: Responses of European Diadromous Fish to Climate Change. Challenges for Diadromous Fishes in a Dynamic Global Environment. A. Haro, K. L. Smith, R. A. Rulifsonet al. Bethesda, Amer Fisheries Soc. **69: 175-193.**
•Schindler, et al. (2008). Climate Change, Ecosystem Impacts, and Management for Pacific Salmon. Bethesda, MD, ETATS-UNIS, American Fisheries Society.
•Beamish, R. J., R. M. Sweeting, et al. (2009). Planning the Management of Pacific Salmon in a Changing Climate. Challenges for Diadromous Fishes in a Dynamic Global Environment, Amer Fisheries Soc. **69: 155-173.**
Limburg, K. E. and J. R. Waldman (2009). Dramatic Declines in North Atlantic Diadromous Fishes. Bioscience **59(11): 955-965.**

Battin, J., M. W. Wiley, et al. (2007). Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences* **104**(16): 6720-6725.

Examining the habitat of Chinook salmon populations in the Pacific, the authors found through modeling efforts, that climate change will adversely affect areas with a rain-snow transition. Habitats targeted for management and restoration will be at greater risk in high-elevation areas and make recovery efforts more difficult based on two climate scenarios. Climate models were used to predict changes in stream temperature during spawning, peak flow during egg incubation and minimum flow during spawning which were then incorporated into current Chinook salmon population models.

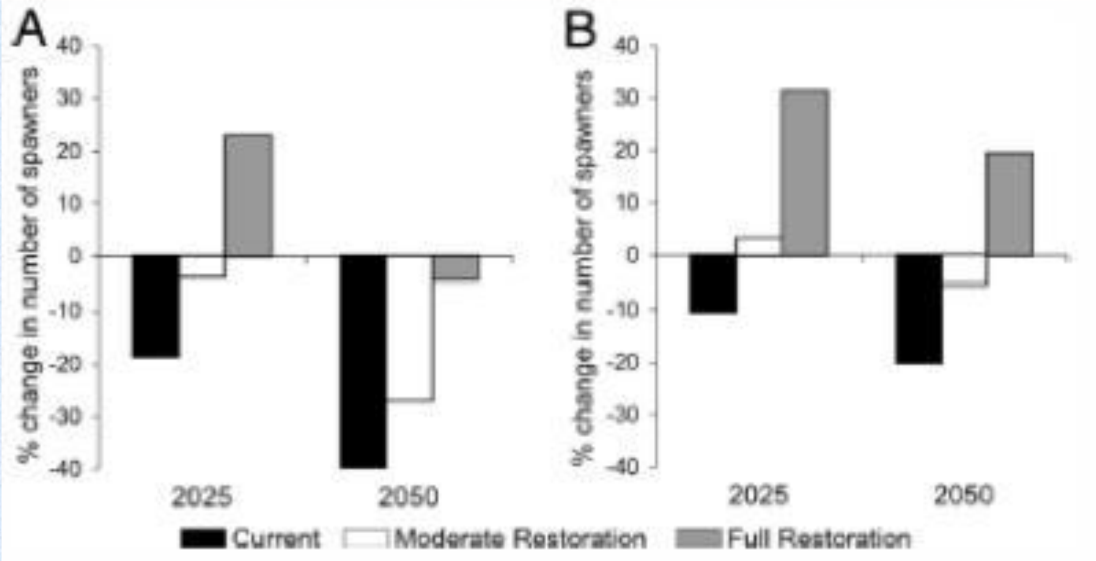

Fig. 4. Basin-wide percent change from 2000 in numbers of spawning Chinook under different combinations of climate change and habitat restoration for the GFDL R30 (*A*) and HadCM3 (*B*) climate models.

Lassalle, G., M. Beguer, et al. (2008). Diadromous fish conservation plans need to consider global warming issues: An approach using biogeographical models. *Biological Conservation* **141**(4): 1105-1118.

While many diadromous fish are protected under international law, restoration and management efforts do not adequately take into consideration the threats brought by climate change. Models based on distribution, environmental variables and stream geography demonstrate that climate change will lead to a significant reduction in geographic range for diadromous species. Models incorporating climate change predictions are a valuable tool to determine how future species distributions may change.

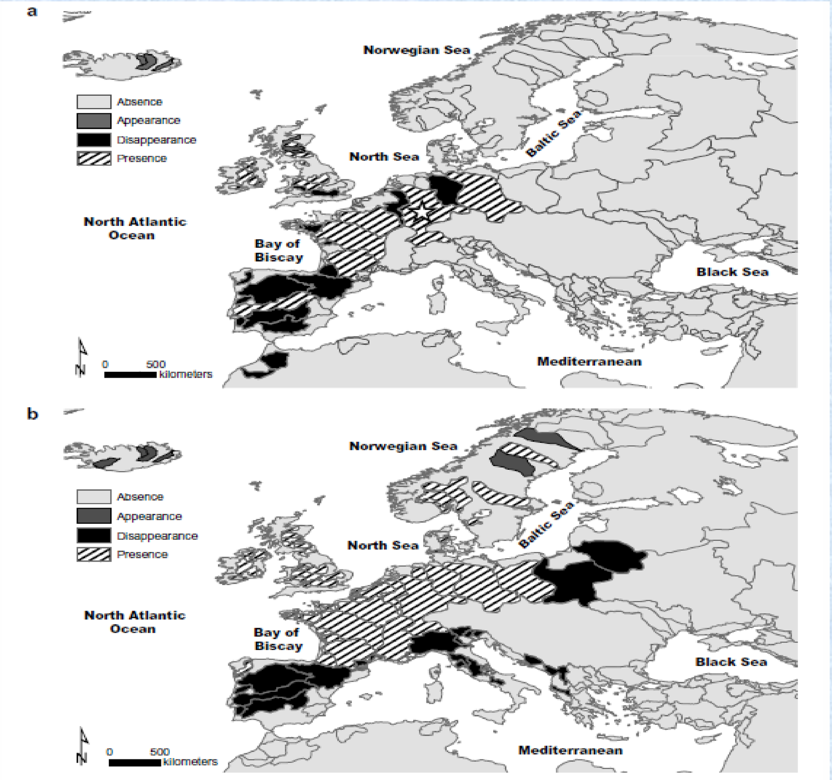

Fig. 3 – Potential distribution range of two diadromous fish species under projected climate conditions at the end of the 21st century. (a) *Alosa alosa* and (b) *Petromyzon marinus*. The projections were computed using our biogeographical models, the pessimistic A2 emission scenario and HadCM3 GCM. The Rhine basin is shown with a white star on the *A. alosa* distribution map.

Rijnsdorp, A. D., M. A. Peck, et al. (2009). Resolving the effect of climate change on fish populations. *ICES Journal of Marine Science: Journal du Conseil* **66**(7): 1570-1583.

This paper sets out to provide a framework to shape future studies on the impact of climate change on fish populations. Focusing on the effects of environmental forcings at each successive life stage and the impact they will have on the life cycle as a whole, the authors propose a means to test hypotheses through modeling efforts.

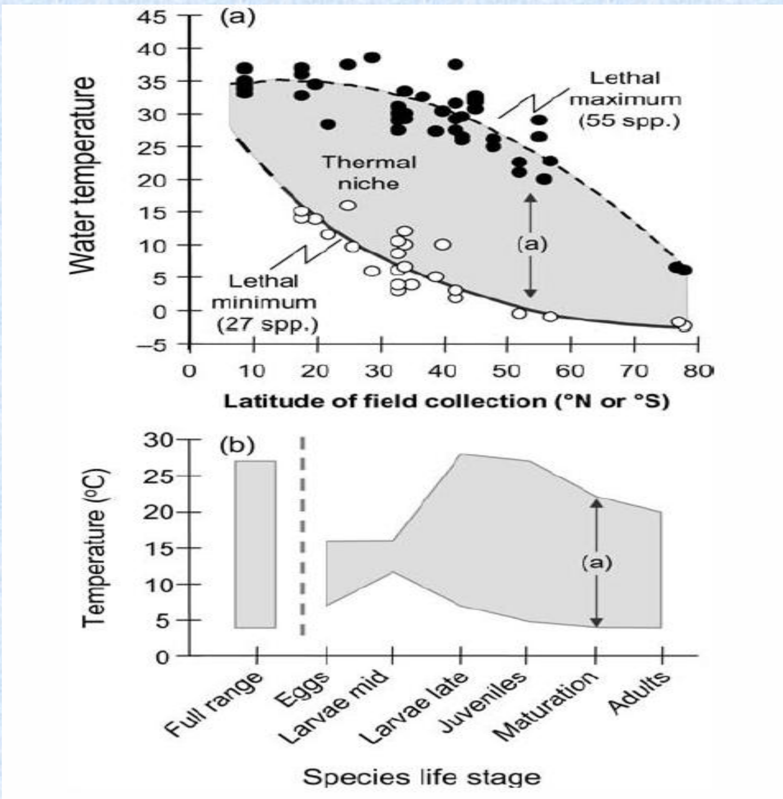

Figure 4. Conceptual diagram of the changes in suitable habitats (based on water temperature) with (a) latitude of the species and/or population and (b) by life stage. The arrow (a) denotes a range of tolerable temperatures measured for adults during maturation and spawning. Data in a and b are from MAP (unpublished data) and Irvin (1974).

Schweiger, O., J. Settele, et al. (2008). Climate change can cause spatial mismatch of trophically interacting species. Ecology **89**(12): 3472-3479.

Climate change in dispersing species is likely to cause a spatial mismatch of interactions. Species that regularly interact such as a species with its food source or with a keystone species may be spatially separated as distribution patterns become heterogeneous as a response to climate change and the physiological ability to withstand changes. This is of particular concern with diadromous fish species whose ranges are already shifting towards higher latitudes and facing changes to spawning timing as a result of flow and temperature regime shifts.

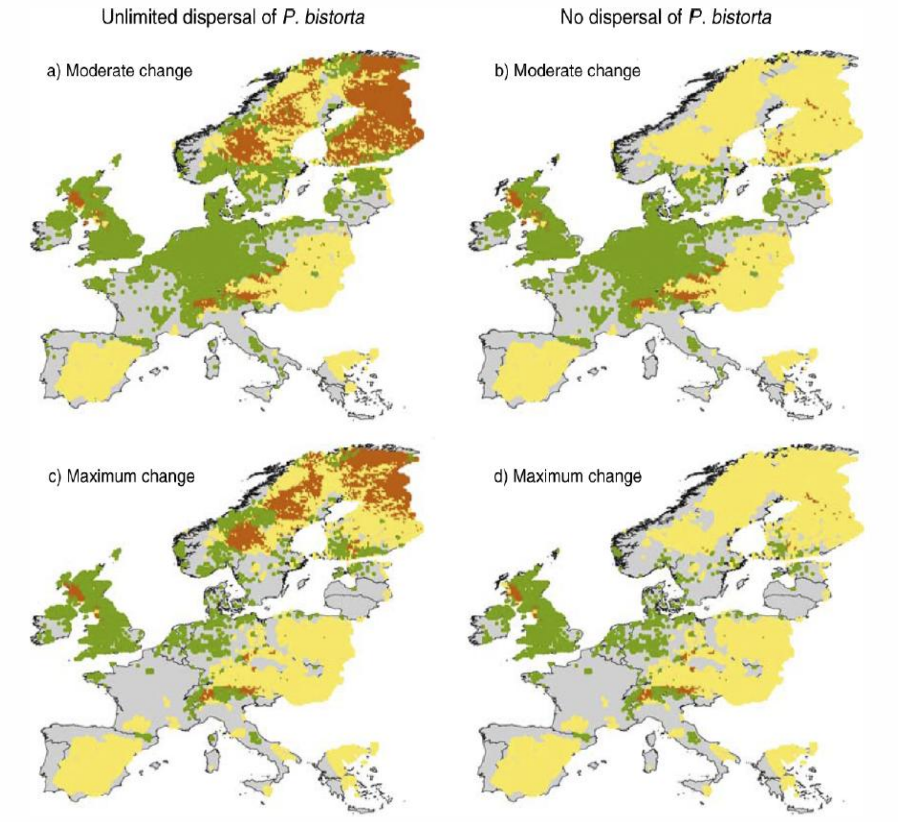

FIG. 3. Match and mismatch of projected niche spaces of *Polygonum bistorta* and *Boloria titania* for (a, b) moderate and (c, d) maximum global-change scenarios for 2080 under the assumption of unlimited (a, c) and no (b, d) dispersal of *P. bistorta*. Green indicates niche space of *P. bistorta*; yellow indicates niche space of *B. titania*; brown indicates overlap of both (potentially realized niche space of *B. titania*).

Join the Diadromous Species Restoration Research Network for information about research, funding and job opportunities, restoration news, and conferences and meetings.
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