Optimal placement of Marine Protected Areas

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Overfishing can lead to the reduction or elimination of fish populations and the degradation or even destruction of their habitats. This can be prevented by introducing Marine Protected Areas (MPA's), regions in the ocean or along coastlines where fishing is prohibited. MPA's can also lead to larger fish densities outside the protected area through spill-over, which in turn may increase the fishing yield. A natural question in this context, is where exactly to establish an MPA, in order to maximize these benefits. We address this problem along a one-dimensional stretch of coast-line, by first proposing a model for the fish dynamics. Fish are assumed to move diffusively, and are subject to recruitment, natural death and harvesting through fishing. Our problem is then cast as an optimal control problem for the steady state equation corresponding to the PDE which models the fish dynamics. The cost index being maximized is a weighted sum of the average fish density and the average fishing yield. We show that optimal controls exist, and will see that the form of an optimal control -and hence the location of the MPA- is determined by two key model parameters, namely the length of the coastline, and the weight of the average fish density appearing in the cost index. If these parameters are large enough -and precisely how large, can be calculated exactly- our results indicate when and where an MPA should be established. The main mathematical tool used to prove our results is Pontryagin's maximum principle.