
Integrating Dynamic Ocean Management (DOM) and Real-Time Climate Indices into Harvest Strategies for Fish Stocks

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Abstract

Traditional fisheries management often relies on static spatial boundaries and historical averages that fail to account for the rapid, climate-driven fluctuations of the modern ocean. As marine species shift their distributions and productivity levels in response to warming and acidification, the "stationarity" assumption in stock assessments has become a liability. This article explores the integration of Dynamic Ocean Management (DOM)—management that changes in space and time based on near real-time data—and Real-Time Climate Indices (e.g., ENSO, PDO, and local thermal anomalies) into formal Harvest Control Rules (HCRs). We argue that this synthesis provides a "climate-ready" framework capable of mitigating overfishing risks, reducing bycatch, and stabilizing economic yields in an increasingly volatile environment.

Keywords: Dynamic Ocean Management, Harvest Control Rules, Real-time Climate Indices
Climate-adaptive Fisheries, Marine Spatial Planning

1. Introduction: The Crisis of Non-Stationarity

The global ocean is warming at an accelerated rate, with 2023 and 2024 recording some of the highest thermal increases since the 1950s. This heating is not uniform; it manifests as "hotspots" and "dead zones" that disrupt the biological stability of fish stocks (IOC-UNESCO, 2024). Traditional management models often assume that environmental conditions will remain within historical bounds, a concept known as stationarity. However, climate change is fundamentally altering the productivity and distribution of marine fisheries, rendering these static models insufficient. Failure to adapt harvest rates to these shifting productivities increases the risk of stock collapse and long-term economic loss (OECD, 2025).

Current fisheries frameworks are struggling to manage ecosystem impacts in such a highly dynamic environment (Dunn et al., 2016). When fish stocks migrate across traditional management boundaries, it creates "overfishing incentives" where losing regions may increase harvest to offset losses, while gaining regions increase effort to capitalize on new arrivals. This phenomenon, exemplified by historic conflicts like the "Mackerel War," highlights the urgent need for a governance structure that moves as fast as the fish do (OECD, 2025). Dynamic Ocean Management (DOM) offers a solution by integrating biological, oceanographic, and social data in near real-time to align management scales with ecological scales (Dunn et al., 2016).

The integration of climate-ready management is no longer a theoretical luxury but a practical necessity for food security. Approximately 82% of worldwide catches come from stocks shared across neighboring Exclusive Economic Zones (EEZs), making them highly vulnerable to climate-induced shifts (FAO, 2026). By shifting from static time-area closures to grid-based, real-time management, fisheries can achieve a significantly higher reduction ratio of bycatch to target catch (Dunn et al., 2016). This transition requires a multi-faceted approach, incorporating everything from enhanced monitoring to the adjustment of biological reference points (Responsible Seafood Advocate [RSA], 2026).

2. Theoretical Framework of Dynamic Ocean Management (DOM)

DOM is defined as management that evolves in space and time in response to the shifting nature of the ocean and its users. Unlike traditional spatial management, which partitions the ocean into fixed regions with permanent regulations, DOM utilizes technological advances to regulate activities across finer temporal and spatial scales (Hobday et al., 2014). These scales can range from seasonal adjustments to real-time closures lasting only days or weeks. The capacity for DOM is bolstered by the rise of electronic logbooks, vessel monitoring systems (VMS), and high-resolution environmental data (Dunn et al., 2016).

The efficacy of DOM lies in its ability to address previously "intractable" ecological patterns, such as niche partitioning, predation, and social aggregations. Empirical evidence suggests that dynamic measures are 100 to 200 times more efficient than annual time-area closures in terms of the area-days required achieving conservation goals. By targeting specific "hot-spots" rather than broad swaths of the ocean, DOM reduces the amount of target catch that must be forgone to protect sensitive species. This precision is critical for maintaining the economic viability of fleets while adhering to strict sustainability mandates (Dunn et al., 2016; Chukwu and Kombo 2019; Chukwu and Oyanna 2002).

Implementing DOM requires robust scientific, technological, and legal capacity (Hobday et al., 2014). While the technological tools—such as satellite-derived sea surface temperature (SST) and ocean color—are largely available, they remain underutilized in policy applications (Hobday et al., 2014). Effective DOM must bridge the gap between high-resolution science and enabling policy, ensuring that real-time data can legally trigger management actions (Hobday et al., 2014). This requires a shift in governance from rigid, multi-year plans to flexible, "climate-responsive" frameworks (RSA, 2026).

3. Integrating Real-Time Climate Indices into Harvest Control Rules (HCRs)

Harvest Control Rules (HCRs) are the "if-then" statements of fisheries management, determining how much can be fished based on the current state of the stock. Integrating real-time climate indices into these rules allows managers to adjust harvest levels before a stock collapse occurs. For instance, an HCR might be programmed to automatically reduce the Total Allowable Catch (TAC) if a specific climate index, like the El Niño Southern Oscillation (ENSO), crosses a predetermined threshold that historically correlates with poor recruitment. This "precautionary buffer" provides a safety net against environmental volatility (RSA, 2026).

Climate-driven shifts are already forcing species into new thermal niches, causing regional declines in maximum sustainable yield (MSY) by as much as 35% in some areas (Alnafissa *et al.*, 2024). By incorporating real-time environmental indices into stock assessments, managers can provide more accurate science advice. For example, the use of pre-recruit indicators and environmental indices in the Northwest Atlantic has helped reduce uncertainty in stock assessments for species like lobster and cod (RSA, 2026; NAFO, 2025). These indices serve as early warning systems, allowing for adaptive, area-specific management adjustments (RSA, 2026).

The transition to climate-informed HCRs is facilitated by the fact that nearly half of all "climate-ready" actions can be implemented within existing legal frameworks. There is no need for a total legal overhaul; rather, managers can leverage current structures to adopt flexible harvest strategies. This includes adjusting biological reference points—such as the biomass level that supports MSY (BMSY)—to reflect current rather than historical environmental states. Such reforms are projected to maintain global fisheries health and profits under all but the most severe emissions scenarios (RSA, 2026).

4. Case Studies and Empirical Evidence

The Labrador Sea and the Northwest Atlantic provide a clear example of how environmental indices are being operationalized. Annual reports now track physical, chemical, and biological oceanographic conditions, providing the data necessary for the Standing Committee on Fisheries Science (STACFIS) to make informed decisions. These indices include measurements of salinity, temperature, and primary production, which are critical for understanding the "state of the ocean" in a given year. This high-frequency monitoring allows for a more nuanced understanding of how multidecadal variability interacts with short-term climate shocks (NAFO, 2025).

In tropical and temperate regions, the stakes are even higher, as productivity is predicted to decrease significantly. Regional discrepancies in food and profits are already emerging as organisms shift toward the poles. In areas like the Gulf of Guinea, rising ocean temperatures

can suppress upwelling, leading to the collapse of local fishing activities. Implementing DOM in these contexts—such as real-time monitoring of upwelling strength—could allow for "move-on rules" that protect remaining aggregations and prevent the "extinction" of local fisheries (Dunn et al., 2016).

Technological capacity for DOM is particularly strong in developed regions, but regional variations remain a challenge (Hobday et al., 2014). While some fisheries use real-time closures to manage bycatch with high efficiency, others still rely on "business-as-usual" models that exacerbate climate impacts (Dunn et al., 2016). The OECD Review of Fisheries 2025 emphasizes that sustainable and resilient fisheries require better policies that prioritize the health of marine resources in a changing climate. The successful integration of these tools into global practice will depend on increased collaboration between governments, scientists, and the private sector (OECD, 2025). .

5. Challenges and Future Directions

Despite the clear benefits, several barriers to the widespread adoption of climate-integrated DOM persist. One major hurdle is the mismatch between the rapid pace of climate change and the slower pace of policy change (Hobday et al., 2014). Additionally, there is an "opportunity cost of inaction"; delays in implementing adaptive reforms could compound vulnerabilities as climate impacts accelerate. Managers must also be wary of "maladaptation"—hasty innovations that might unintentionally harm fleets or ecosystems (RSA, 2026).

Future efforts must focus on:

- **Building Stakeholder Capacity:** Improving collaboration between science, management, and the fishing industry to ensure buy-in for dynamic rules (RSA, 2026).
- **Expanding Ocean Observation:** Investing in the "critical infrastructure" of observation to manage risk and meet future demands. (IOC-UNESCO, 2024). .
- **Piloting Diverse Contexts:** Testing climate-ready actions in both data-rich and data-poor fisheries to find scalable solutions (RSA, 2026).
- **Cross-Boundary Governance:** Developing international agreements that account for fish stocks migrating across EEZs to prevent "mackerel wars" (IOC-UNESCO, 2024).

As the ocean continues to warm at an unprecedented rate, the survival of global fisheries depends on our ability to manage them as the dynamic systems they are . By integrating real-time climate indices into harvest strategies, we can move from a reactive stance to a proactive, resilient future for marine resources (RSA, 2026).

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