Reviews in Aquaculture

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OPINION

Unmarked Escapees Undermine Policy and Public Trust in Chilean Salmon Aquaculture

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1 | Introduction

Fish escapes from open water net pens around the globe present persistent and unresolved challenges for aquaculture governance, environmental stewardship, and industry accountability. These escape events are widely recognized as disturbances to ecosystem services and functions [1], carry significant social and financial repercussions [2], and have prompted regional prohibitions on net-pen farming [3]. Particularly concerning is the potential for escaped fish to reproduce successfully [4], which can lead to genetic introgression with wild conspecifics or negative interactions with other native species [5] and, ultimately, the establishment of undesired, non-native populations [6]. Yet a critical barrier to effective fisheries regulations and management is the lack of certainty: *Are these fish caught at sea, rivers, and lakes recent escapees, or were they born in the wild?* This ambiguity obscures ecological assessments and undermines both policy enforcement and conservation planning.

Nowhere is this environmental policy gap more pressing than in southern Chile, where farming non-native Atlantic salmon (*Salmo salar*), coho salmon (*Oncorhynchus kisutch*), and rainbow trout (*O. mykiss*) in sea net pens has become a pillar of the national economy. Over 100 mass salmon escapes were reported in the last three decades, overlapping with a period in which various trout and salmon populations were reported to establish throughout the region. Nowadays, ecological knowledge on naturalized salmonids is blurred by the mixed presence of aquaculture-origin fish and subsistence fisheries of any salmonid banned by rules seeking to avoid theft and commercialization of farmed fish. Therefore, we argue that standardized, mandatory marking of all fish farmed in open water net pens should be a policy priority. Reliable data on the origin of wild-caught salmon is crucial for informed decision-making, ecological research, and restoring public trust in open water aquaculture in Chile.

2 | A Policy Gap Exposed in Chile, the Second Largest Salmon Producer in the World

Between 2010 and 2020, over 2.85 billion juvenile fish were stocked across 1343 marine aquaculture sites in southern Chile [7], generating 63.6 billion USD in export revenue and making salmon the country's second-largest export commodity behind copper [8]. However, the sea net pen industry continues to struggle with a tenuous social license, largely due to public concern over environmental impacts, including fish escapes [2, 8]. Similar tensions are emerging in high-production regions of Europe, North America, Oceania, and Asia, underscoring the global relevance of powerful mitigation measures, including a mandate to mark aquaculture escapees so they can be differentiated in the fishery.

Regulatory and technological advances have reduced the number of mass escape events over the past 25 years (Figure 1), now primarily associated with extreme weather events and infrastructure failures [9]. However, the size of each event has grown as farms hold more biomass [10]. Larger escape events heighten ecological risk by increasing the number of escapees that may reach spawning areas simultaneously, increasing the

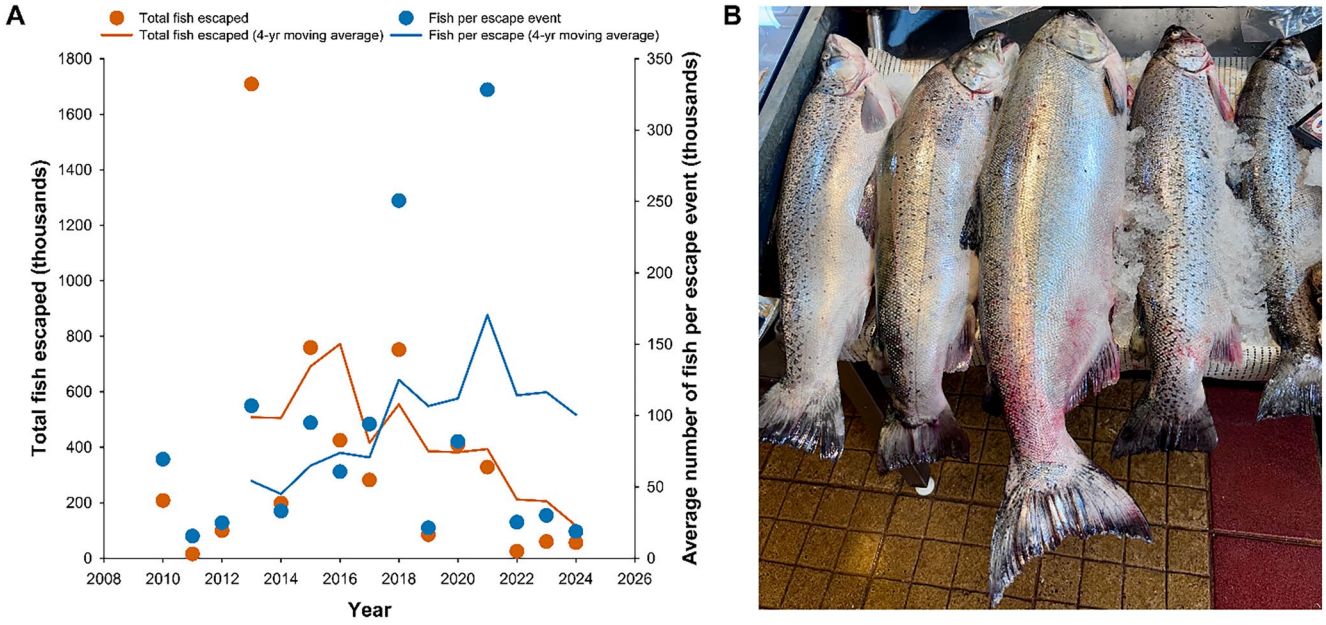


FIGURE 1 | (A) Total fish in mass escapes (> 1000 fish, orange circles) and average fish per event (blue circles) reported yearly from 2010 to 2024 in southern Chile. Trendlines show a large decrease in escaped fish yearly (orange), whereas the average size of each escape event (blue) has almost doubled over the last two decades. *Source:* Supporting Information S1. (B) Atlantic and Chinook salmon of unknown origin being sold at a local fish market in Puerto Montt, southern Chile in 2024 (photo credit: Ivan Arismendi).

likelihood of successful reproduction. To avoid large environmental fines (up to 5000 Annual Tax Units, ~USD 4.4 million in 2025), Chilean rules require companies to recapture ≥ 10% of escapees within 60 days, yet recovery rates rarely exceed 6%. Moreover, recapture efforts often retrieve salmonids of unknown origin, suggesting a problem of *chronic leakage*—small, routine losses from fish transfers, pharmaceutical treatments, net maintenance, and other daily operations that typically go unreported.

Although recreational fishing has expanded steadily in Chile over the past few decades, existing regulations still prevent coastal fishing communities from benefiting from these emerging fishery resources. Under the current Fisheries and Aquaculture Law, artisanal fishers are prohibited from commercializing salmonids. The sole exception is a recently regulated salmon fishery limited to the coastal areas of the Araucanía and Los Ríos Districts, where self-sustaining populations of migratory Chinook salmon (*O. tshawytscha*) have become established. In addition, a seasonal recreational fishery for salmonids is permitted in freshwater systems from late spring through early fall, subject to strict size and daily catch limits. Recreational anglers routinely capture rainbow trout, brown trout, and both Pacific (including Chinook) and Atlantic salmon; however, the precise proportions and origins of these fish (e.g., recent escapees vs. naturalized individuals) remain unknown to fishers, authorities, aquaculture operators, and researchers.

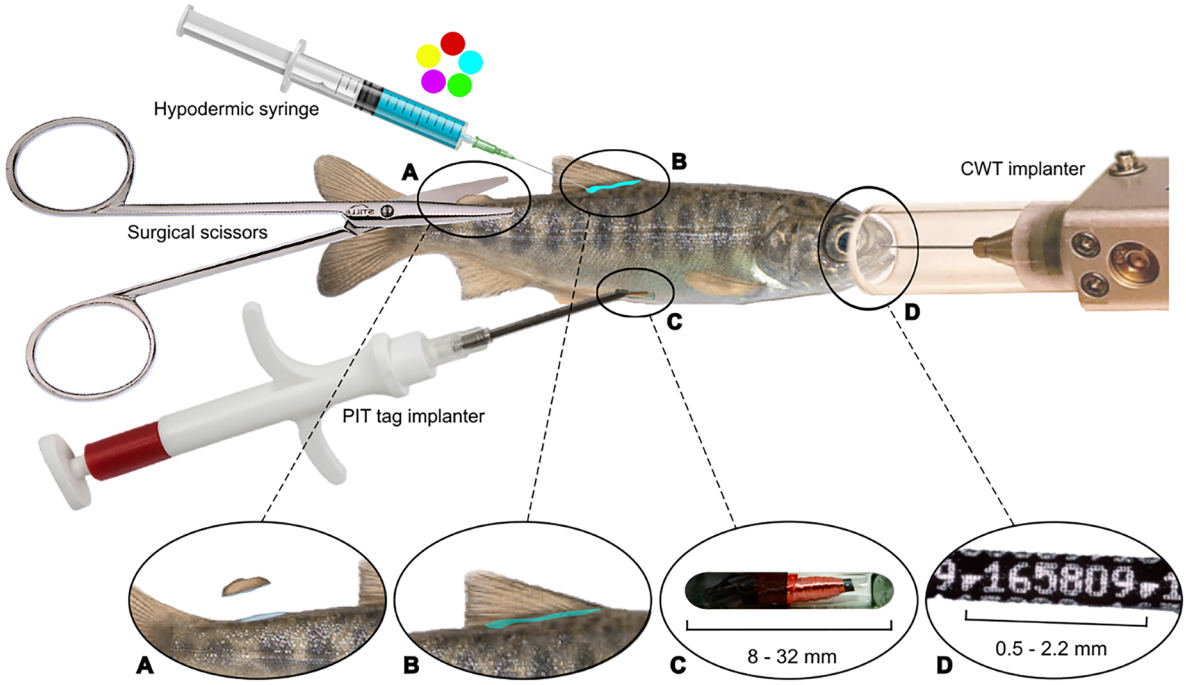
3 | Opportunity Lost for Artisanal Fishers and the Marking Debate in Congress

Selective harvest of naturalized salmonids by small-scale fishers offers a dual benefit: ecological impact mitigation and local income generation [11]. Yet, Chilean law long prohibited the capture and commercialization of any salmonid outside of farms. A January 2023 transitory article removed penalties [12], but commercializing bycatch remains illegal [13]. As a result, salmonid landings bypass regulatory channels, evading reporting requirements and undermining both conservation and potential economic benefit. The blanket prohibition on commercialization, initially designed to prevent theft and deliberate releases from farms, no longer reflects the current reality of widespread self-sustaining populations. Moreover, it overlooks a valuable opportunity to incorporate naturalized salmonids into a formally regulated fishery [4, 11].

Bill 16,78421, introduced April 2024, amends the Fisheries and Aquaculture Law 18.892 to require individual PIT or coded-wire tags for every farmed salmonid (Figure 2). While technically feasible, industry groups argue the measure is prohibitively expensive and of limited direct benefit [14]. The proposal now risks indefinite delay or veto.

4 | A Visible Solution: Adipose Fin Clipping for Aquaculture Accountability

We urge legislators to consider a pragmatic and widely used alternative: routine adipose-fin removal for all hatchery-raised salmonids destined for net pens (Figure 2; Supporting Information S1). Common in hatchery operations globally, the clip is low cost (< USD $0.01 per fish), visible to non-experts, and easily integrated into existing workflows. It is also compatible with PIT or genetic tools for situations requiring precise traceability when needed. A universal external mark would: (i) close the current information gap and strengthen enforcement capacity, (ii) legitimize selective harvest of naturalized fish (those



	Adipose fin removal	Visible implant elastomers (VIE)	Passive integrated transponders (PIT)	Coded wire tags (CWT)
Marking procedure	Fin clip with surgical scissors or automatic machine	Manual sub-epidermal polymer injection	Manual intra-peritoneal PIT tag injection	Manual hypodermal wire injection or with automatic machine
Reading procedure	Naked-eye observation	Naked-eye observation	Trans-abdominal scanning	Electronic detection, extraction, microscopy
Long-term retention (1-3)	97 - 100%	57 - 87%	91%	96 - 99.5%
Cost per fish (4)	$0.015 - 0.025	$0.11	$1.50 - 5.50	$0.06 - 0.136
Handling time (5)	3 - 4 sec	30 - 120 sec	30 - 60 sec	5 - 10 sec
Information level	Binary	Categorical	Alphanumeric (10 - 15 digits)	Alphanumeric (6-digit)
Example use	Source discrimination (farmed vs. naturalized)	Hatchery identification	Individual identification	Cohort identification

FIGURE 2 | Comparison of leading fish marking methods used in salmonid fisheries and aquaculture, including coded-wire tags, PIT tags, and external marks (see Supporting Information S1).

with intact fins) by artisanal or recreational fishers, (iii) maintain accountability pressure on farm operators, and (iv) provide a reporting mechanism for salmonid landings—similar to those already implemented for other artisanal fisheries, where fishers log catch data through standardized landing forms. The last will represent the basis for the first systematic dataset on propagule pressure and range expansion, even if individual escapees could not be traced back to a specific farm.

Chilean farms already anesthetize and individually handle smolts for vaccination, and automatic fin clipping systems capable of processing > 100,000 fish per day are commercially available [15]. Adipose-fin clipping is well established, with minimal welfare impacts and very low rates of regrowth (Supporting Information S1).

5 | Aligning Policy With Ecological Reality

Chile's salmonid range expansions stem from both deliberate historical introductions and persistent contemporary escapes [4]. Atlantic salmon are mostly recent escapees; Chinook salmon are predominantly naturalized; rainbow trout and coho salmon are mixed. No routine system verifies origin at landing, leaving enforcement reliant on unreliable visual cues.

The current blanket prohibition on selling nonnative salmonids, initially aimed at deterring theft and avoiding the spread of invasive species, is outdated. Today, it hampers ecosystem-based management and denies potential income for coastal communities. Allowing licensed, monitored harvest of wild-origin fish (those without clipped fins) while holding farms accountable

for marking escapees would better align policy with reality and help balance conservation with economic opportunity.

A central challenge is the anticipated opposition from recreational fishing sectors, who have seen decades of investment and tourism grow around introduced salmonids. Proposals to expand artisanal fishing have previously faced resistance, including during the creation of the Chinook salmon exception fishery in La Araucanía and Los Ríos Districts. To prevent repeating this cycle, any expansion of artisanal access must involve inclusive, regionally grounded planning. Co-developed site-specific quotas, seasonal limits, and gear restrictions can reconcile competing interests.

We therefore recommend that Chile amend the Fisheries and Aquaculture Law to mandate adipose-fin clipping for all net-pen salmonids and to legalize the commercialization of unclipped (wild-origin) fish under a licensed, monitored framework. This dual approach will support ecological resilience, promote equitable resource use, and restore public confidence in Chile's aquaculture governance. A collaborative framework involving government agencies, industry, scientists, and local communities will be key to success.

The supplement provides an overview of available tagging technologies and outlines the advantages of adipose-fin removal to support the arguments presented in this Opinion.

Author Contributions

Conceptualization: J.A.O., I.A.; Visualization: J.A.O., I.A.; Writing – original draft: J.A.O.; Writing – review and editing: J.A.O., I.A., S.M.W., T.P.Q., E.B.T., B.E.P., D.S.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** Supporting Information.

Biographies

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