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Research Article

Monitoring data poor small-scale estuarine fisheries: a proposal from the striped mullet (*Mugil cephalus*) fishery in the Rapel River, Chile

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ABSTRACT. Chile has a relatively long history of monitoring and managing large-scale commercial fish stocks. However, many other small-scale fisheries, particularly those operating in estuaries, usually lack basic fisheries and biological information. International experience indicates that a monitoring system designed for large-scale stocks cannot simply be resized to address the complexity, relatively low total economic value, and the large number of actors and supply chains in small-scale fisheries. This article proposes a strategy to monitor data-poor fisheries operating in estuaries. The striped mullet (*Mugil cephalus*), locally known as "lisa", in the Rapel River, central Chile, was selected to establish a pilot monitoring program for small-scale fish resources. From May 2022 to May 2023, fisheries information, including fleet description, catch and effort data, and fish biological attributes such as length and weight, were collected and described for the first time in the region. Drawing insights from this case study, we propose developing a generic monitoring system tailored specifically for monitoring fish stocks in estuaries. This conceptualization is based on: i) change agents, who are individuals trained to work with both the social and biological dimensions of each coastal fish stock; ii) experienced fisheries scientists outside government agencies; and iii) local fishers' knowledge to provide constant feedback for adapting temporal and spatial scales for monitoring. This monitoring scheme is cost-effective and can be efficiently replicated in other estuarine fisheries in Chile.

Keywords: *Mugil cephalus*; estuarine fisheries; fishing monitoring; Chilean small-scale fisheries

INTRODUCTION

Chile has a well-established history of monitoring, assessing, and managing marine fish stocks. Currently, the country oversees the management of 15 fish stocks using a total allowable catch (TAC) approach, with estimates derived from integrated stock assessment models. These models require intensive monitoring of catches, effort, size/age structures, abundance indices, and life history parameters (Wiff et al. 2016). The most significant fisheries, in terms of landings and fishing history, are Chilean hake (*Merluccius gayi gayi*), southern hake (*M. australis*), common sardine (*Strangomera bentincki*), anchoveta (*Engraulis ringens*), and jack mackerel (*Trachurus murphyi*). Three institutions monitor and manage these large-scale

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commercial marine fish stocks, each playing a specific role. The Servicio Nacional de Pesca (SERNAPESCA, "National Fisheries Service") is a government agency inspecting landings and quota compliance in the main landing harbors. The Instituto de Fomento Pesquero (IFOP, "Fisheries Development Institute") is a technical agency responsible for monitoring, conducting stock assessments, and collecting fisheries and biological information with a network of scientific observers. Finally, the Subsecretaría de Pesca y Acuicultura (SUBPESCA, "Undersecretariat of Fisheries and Aquaculture"), a government regulatory agency assisting in managing these fisheries. This scheme for landing estimations, monitoring, assessment, and management is firmly established in Chile and, although not without weaknesses, enjoys a good international reputation.

Despite the well-established management scheme for marine commercial fisheries in Chile, there are numerous small-scale fisheries where basic monitoring information is, at best, fragmented and particularly problematic for small-scale fisheries operating in estuarine areas such as rivers, river mouths, and the river-sea interface (hereafter referred to as estuaries). Currently, the main species targeted by the small-scale fishing sector in estuaries include Patagonian blennie (*Eleginops maclovinus*), sea silverside (*Odontesthes regia*), striped mullet (*Mugil cephalus*), and more recently, the naturalized chinook salmon (*Oncorhynchus tschawytscha*) in southern Chile (Astorga et al. 2008, Bravo et al. 2019). While these fisheries have sparse official landing statistics and practically no enforcement, they play a crucial role in local livelihoods. However, given that monitoring systems are already operating at full capacity in managing the main marine fisheries, the vast expanse of the country's rivers and estuaries, often located in remote areas, poses a significant challenge for monitoring coastal fisheries in these estuarine environments. Small-scale estuarine fisheries typically operate on a small, often subsistence scale, mainly using small gillnets and boats less than 5 m long. Fishers typically cover short distances during their daily trips from landing areas. Assessing and managing these fish species is challenging due to the sparse distribution of fishing activities, making it difficult for fishing authorities to register key information such as catches and fishing efforts. Moreover, catches supply local markets primarily and play an increasingly important role in supporting the local tourism industry.

Weaknesses in monitoring small-scale stocks are not unique to Chile. Formal management agencies often overlook small-scale estuarine fisheries (Begossi 2010). According to Prince (2010), the discrepancy between well-monitored commercial fisheries and neglected small-scale fisheries results from a misalignment of both temporal and spatial scales between ecosystems and management institutions, indicating a common manifestation of “the tyranny of the scale” problem. In this context, top-down decisions for monitoring large stocks of economically important fisheries cannot simply be resized to address the complexity, relatively low total economic value, and the large number of actors and supply chains in small-scale fisheries, such as those operating in estuaries. Therefore, alternative models are needed to monitor these small-scale fish stocks effectively and cost-effectively. Prince (2010) proposed a generic approach in which fishers play an active role, and decisions have a reversal and feedback path among authorities, institutions, change agents, and fishers. A proposal for effective monitoring of small-scale estuarine fisheries in Chile should be based on a generic approach that can be locally adapted to each fish resource. This approach should rely on four main aspects: 1) change agents: individuals trained to work with each coastal fish stock's social and biological dimensions. These change agents should be recognized and known by the local community, playing a liaison role between fishing communities and agencies to establish a linkage between local and regional scales for fishing monitoring; 2) fisher knowledge: a crucial element in any monitoring approach for these small-scale fisheries, as it provides the basis for determining the temporal and spatial scales at which monitoring should be adapted; 3) cost-efficiency: the monitoring needs to be cost-efficient to collect essential fisheries and biological attributes of the fishing resources; and 4) logbooks and sampling protocols: these should be simple but comply with information requirements, mirroring the standards used by formal agencies such as SERNAPESCA and IFOP.

In this article, we implemented a strategy to monitor data-poor small-scale estuarine fisheries, focusing on the striped mullet, locally known as “lisa”, in the Rapel River (33°54'S), Navidad, O'Higgins Region, central Chile (Fig. 1). We establish a pilot monitoring program for small-scale fish resources, using this fishery as an experimental platform to assess the feasibility of establishing a monitoring program, taking into account both fishery's characteristics and socio-economic factors. Fish species within the *Mugil* genus provide the basis for several small-scale fisheries worldwide. These fish species are catadromous, meaning that juveniles

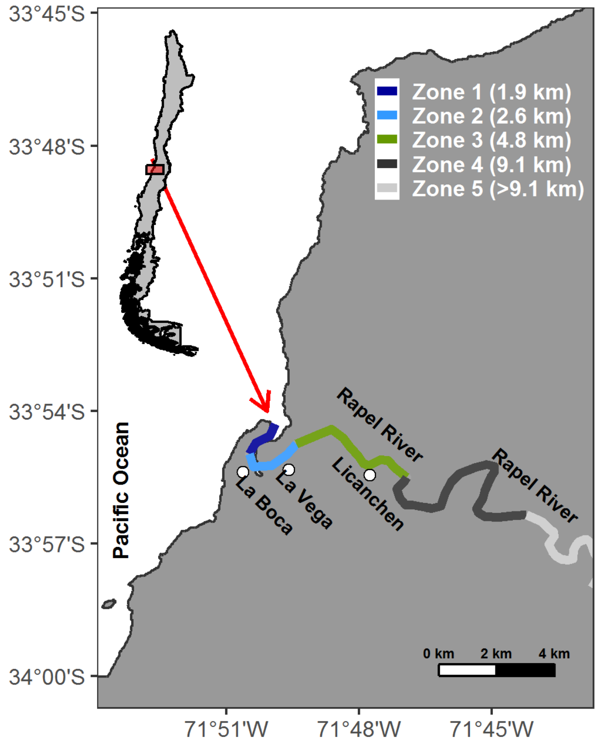

Figure 1. Map of the study area indicating the zones for fishing monitoring. Value in brackets corresponds to the length of each zone in km.

are associated with freshwater/estuarine environments for feeding and growth, while adults migrate to the sea for reproductive purposes (Whitfield et al. 2012). In Chile, a substantial small-scale fishery is developed in the central zone, mainly associated with estuarine zones of the Maipo River (34°13'S), Rapel River, Maule River (35°19'S), and Biobío River (36°48'S). Small gillnet fishing boats operate in estuarine waters close to the coast in these four areas. Their catches are destined for human consumption, either fresh or smoked, in local markets and restaurants (Fig. 2). Additionally, there is an emerging market for using roe for caviar, particularly in the context of striped mullet in the Biobío Region (Ariel Valenzuela, *pers. comm.*).

Despite the significance of the striped mullet for the local economy and food security in estuarine localities in central Chile, more fisheries and biological information are needed for this species. Fragmentary information on landings in the country has been collected by SERNAPESCA since 1950, although fishers primarily report catches without validation from scientific observers. Some scattered biological data have been gathered, including information on parasites (Bargiela 1987) and preliminary biological traits such as growth estimates (Colil 2019, Farías-Salcedo 2022).

The lack of comprehensive fishery and biological information on striped mullets from the artisanal sector in Chile provides an opportunity to test a pilot sampling program. Therefore, the main aim of this research is to propose and evaluate a cost-effective and generic pilot monitoring program for small-scale fisheries in Chile that operate in estuaries, using the striped mullet in the Rapel River as a case study. For the first time in the region, we collected and described fisheries information related to fleet description, catch and effort, and biological attributes such as length and weight.

MATERIALS AND METHODS

Conceptual framework

Following the principles Prince (2010) outlined, Figure 3 illustrates our conceptualization for proposing a monitoring scheme for small-scale estuarine fisheries in Chile. The fishing units are small and confined to specific watersheds, represented by colored dots. These dots may symbolize stock units of the same species or stocks of different estuarine species that share a common area.

A crucial element of our proposal, piloted in this study, is the utilization of "change agents". These agents, well-known and recognized within the local community, are equipped with the necessary training in the technical aspects of biology and fisheries sampling. These change agents can be responsible for sampling a portfolio of stocks as large as cost-effectiveness allows. They should undergo supervision and training in sampling protocols by a university or a consulting group with experienced fisheries biology and sampling design scientists. The size of the group of change agents managed by these institutions would depend on logistical and cost-effective considerations.

These institutions will play a pivotal role in instructing and supervising change agents and collecting and curating the data for transfer to government bodies. In the case of small-scale stocks, the decision-making process involves a two-way path, given that fishers will play a crucial role in shaping the sampling program by providing essential information on strata (zones), species, and temporality. These attributes acknowledge the heterogeneity of stocks. Change agents collect such information to discuss with higher-level institutions, collaboratively adapting the sampling design with fishers. Institutions then negotiate these arrangements with government bodies to match and merge this information with institutional databases.

Figure 2. Fishing operation and sampling of striped mullet in the Rapel River: a) artisanal fishing vessel starting a fishing operation, b) gillnet soaking, c) gillnet retrieval and catch collection, and d) a sampled specimen of striped mullet.

Pilot monitoring program

In the last week of December 2021, two meetings were held with fishers and stakeholders in Navidad at the two main landing harbors, La Boca and La Vega de la Boca (referred to as "La Vega"). These meetings aimed to introduce and discuss the pilot program with fishers, secure support for the required information, and develop the initial prototypes of logbooks. The discussions also included determining the number of fishers contributing to the monitoring program, establishing spatial and temporal scales for sampling, and validating the proposed zone divisions in the Rapel River.

We adopted a structure, such as the information collected by IFOP and SERNAPESCA, to generate the logbooks. The first logbook, "vessels", aims to collect physical information on all boats and fishing gear used to catch striped mullets in the Rapel River. It included physical vessel characteristics such as length, width, type, engine power, and the number of gillnets, materials, and mesh size. This logbook was completed only once for all vessels engaged in striped mullet fishing. The second logbook, labeled as "logbook for catch and effort", involved weekly interviews with fishers conducted by a change agent. This logbook gathered operational aspects, including the number of fishing days, soaking time, fishing zone, crew number, and total catch. Effort was measured in fishing trips, the most common metric for small-scale gillnets.

The Rapel River was divided into five areas based on landmarks suggested and recognized by fishers (Fig. 1). These areas were solely based on the distance from the coast and had different extensions. A preliminary division of the fishing zones was validated with local fishers. The third logbook, named "biological", recorded information such as total length (TL), sex, total and eviscerate weight (g), gonad weight (g), liver weight (g), stomach weight (g), macroscopic maturity staging, and the collection and storage of both sagitta otoliths for further analyses. Additionally, a photograph of each sampled individual was recorded. The last logbook, named "lengths structure", documented the length structure in the catch for those fishers willing to provide their catch for sampling. The results mostly correspond to the vessel, length structures, catch, and effort logbooks. The biological logbook only includes individual length and weight since the reproductive aspects of this species are extensive and beyond the scope of this article.

Vessel characteristics were recorded for the entire fleet targeting striped mullet. Catch and effort information were gathered weekly through interviews with all fishers involved in the striped mullet fishery in the Rapel River. To fill the biological logbook, a random sample of 15 individuals was purchased from local fishers every second week. The logbook for length structures is completed weekly and depends on fishers' willingness to lend their catch for random length recording.

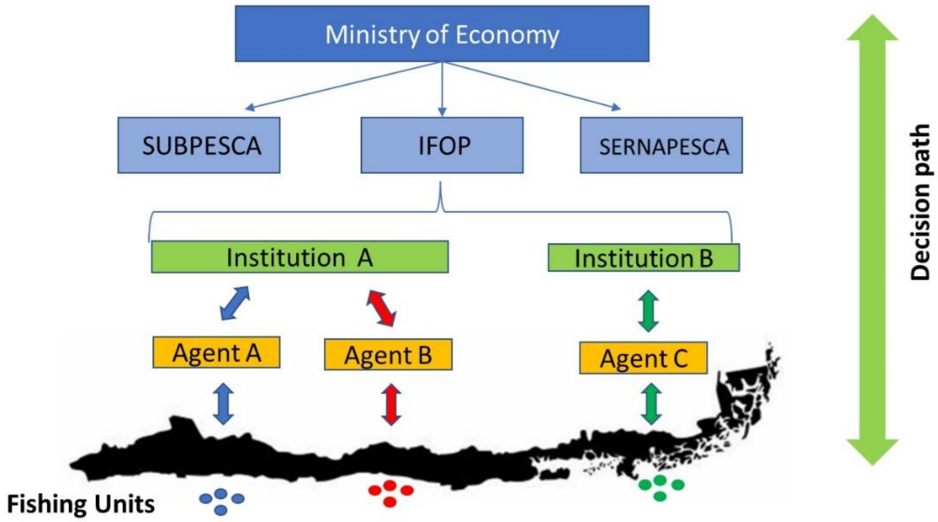

Figure 3. Schematic diagram illustrating the monitoring of small-scale fishing in the river-sea interface. These dots can represent stock units of the same species or stocks of different estuarine species that share a common riverine area. SERNAPESCA: Servicio Nacional de Pesca (National Fisheries Service), IFOP: Instituto de Fomento Pesquero (Fisheries Development Institute), and SUBPESCA: Subsecretaría de Pesca y Acuicultura (Undersecretariat of Fisheries and Aquaculture).

Our co-author, Leonardo Peralta, a marine biologist and resident of Navidad for the past 24 years, served as the change agent for this study. With extensive experience working with local fishers, his mission was to collect the four logbooks mentioned earlier. During a pilot sampling in April 2022, the change agent underwent training by experienced scientific observers from CAPES-UC.

RESULTS

Fishing monitoring

Between May 2022 and May 2023, a total of 11 fishing vessels were registered in our logbook for physical characteristics at two landing harbors, La Boca and La Vega (Table 1). The vessel lengths ranged from 3.5 to 7.3 m (mean = 4.8 m). Most vessels were propelled by oars, with only three using engines. All fishing vessels utilized gillnets, with lengths and widths varying between 50-60 m and 4-9 m, respectively (Table 1). Mesh sizes ranged between 3 and 4 inches, although 2.5-inch mesh sizes were also observed in some trips. Vessels typically carried between 2 and 6 gillnets per fishing trip (Table 1).

Catches of striped mullet exhibited a distinct temporal pattern, with levels exceeding 1500 kg during December and January, while in other months, catches were consistently below 1100 kg (Fig. 4). The lowest catch, recorded in July 2022, was 314 kg. According to fishers, higher catches during the summer months were attributed to the fish's behavior as they migrate to the sea, making them more accessible. Conversely, lower catches in July were influenced by adverse weather conditions, reduced abundance of striped mullet, and increased interactions with fishing gear by sea lions. Fishers often shift their target to Patagonian blennie during winter or engage in other commercial activities.

The size of the fishing fleet, measured by the number of vessels, exhibited a positive temporal correlation with fishing effort quantified in fishing trips (r = 0.77, Table 2), suggesting that an increase in the number of fishing vessels (≥8 vessels) corresponds to a rise in the number of fishing trips (≥23).

Despite the temporal variability in catches, they showed a low correlation with the displayed effort (r = 0.20). Furthermore, the catch per fishing trip (catch rate) demonstrated a negative and moderate correlation with the number of vessels (r = -0.54), which indicates that as more vessels are involved in fishing, catch rates tend to decrease (Table 2). A total of 11746 kg of striped mullet were caught during the study period (Table 2), with most catches (68%) recorded in zone 1 (Fig. 5), representing the mouth of the Rapel River (Fig. 1). The second most important area for catches was zone 3, contributing 16%. In comparison, zones 2 and 4 combined contributed 15% of the total catch (Fig. 5).

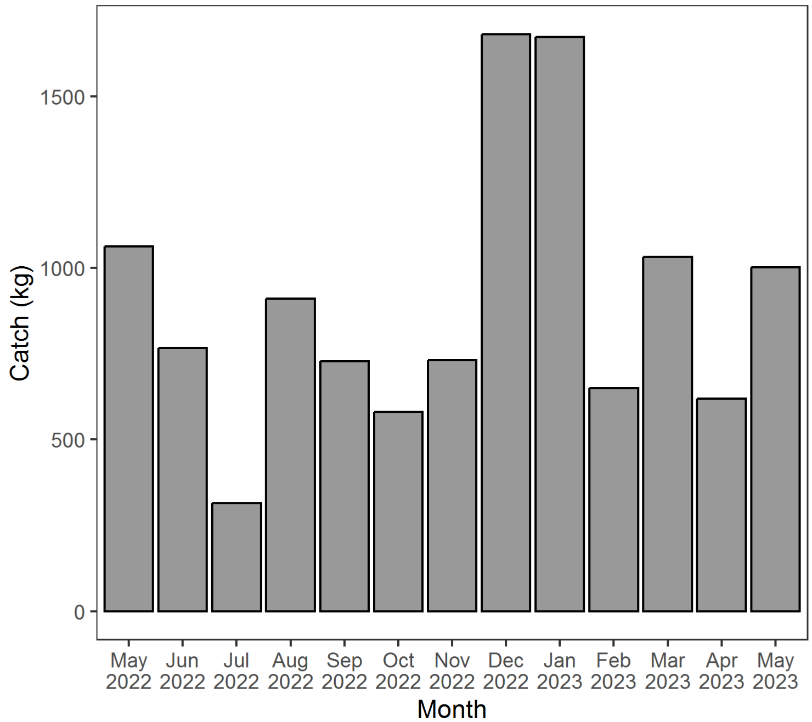

Figure 4. Monthly variations in striped mullet catches in the Rapel River between May 2022 and May 2023.

Table 1. Physical characteristics of fishing vessels and fishing gear used in the catch operation of striped mullet in the Rapel River. Data from May 2022 to May 2023.

Number	Vessel length (m)	Propelling type	Harbor	Gillnet length (m)	Gillnet width (m)	Gillnets per set (n)	Gillnet material	Mesh sizes (inches)
1	3.5	Oars	La Boca	60	5	2	Nylon	4
2	7.3	Engine (115 hp)	La Boca	50	9	3	Nylon	4
3	5.0	Oars	La Boca	60	9	4	Nylon	3
4	4.3	Oars	La Vega	60	6	2	Nylon	4
5	4.3	Oars & Engine (5 hp)	La Vega	60	6	2	Nylon	3.5
6	4.5	Oars	La Vega	60	6	6	Nylon	3.5
7	5.0	Engine (5 hp)	La Boca	50	4	4	Nylon	4
8	5.5	Oars	La Boca	50	6	4	Nylon	4
9	4.3	Oars	La Vega	60	6	4	Nylon	4
10	4.6	Oars	La Boca	50	9	4	Nylon	4
11	4.0	Oars	La Vega	60	6	2	Nylon	4

Furthermore, 90% of striped mullet catches in zones 1 and 2 were landed at La Boca harbor. In contrast, over 85% of catches from the remaining zones landed at La Vega harbor.

Zone 1 emerged as the most frequented fishing area throughout the year, consistently recording the highest catches, exceeding 900 kg in both May of both years and approximately 780 kg during December 2022 and January 2023 (Fig. 6). Monthly catches in zone 2 remained lower, not surpassing 350 kg. In zone 3, catches were concentrated during spring and summer, reaching a peak of 483 kg in December 2022 (Fig. 6). The temporal pattern of catches in zone 4 mirrored zone 3 but with lower levels. Of the total catches recorded in zones 1-2, 91% were landed in La Boca, while 87% of the catches from zones 3-4 were landed at La Vega.

The length structures also exhibit a temporal pattern, revealing variations from unimodal to multi-modal distributions (Fig. 7), with a maximum range of 25 to 79 cm TL for fish caught during May and January 2023, respectively. Individuals smaller than 36 cm TL were observed during autumn (April and May), while

Table 2. Temporal variations in catch and fishing effort for striped mullet in the Rapel River between May 2002 and May 2023.

Year	Month	Total boats	Total trips	Fishing boats	Fishing trips	Catch (kg)	Catch/Fishing trips
2022	May	8	17	7	13	1063	82
	Jun	7	21	6	15	766	51
	Jul	8	22	7	14	314	22
	Aug	9	27	8	23	911	40
	Sep	10	39	10	33	727	22
	Oct	10	31	9	24	581	24
	Nov	10	31	9	26	731	28
	Dec	10	40	10	38	1681	44
2023	Jan	9	44	8	32	1672	52
	Feb	10	37	9	26	650	25
	Mar	10	36	10	31	1032	33
	Apr	11	35	10	26	619	24
	May	9	15	5	9	1002	111
Total		11	395	11	310	11746	38

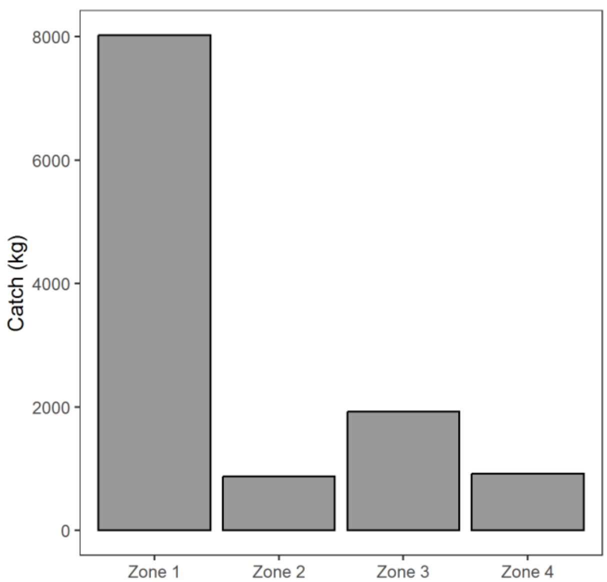

Figure 5. Catches of striped mullet by fishing zones in the Rapel River between May 2022 and May 2023.

fish larger than 42 cm TL were present throughout the year, with a secondary importance noted during April and May 2023 (Fig. 7). From May 2022 to May 2023, 57% of the striped mullet landed at La Boca harbor were juveniles caught in zones 1-2, while 15% of those landed at La Vega harbor were juveniles caught in zones 3-4, (Fig. 8). These results highlight a spatial segregation of size in the Rapel River, with most juveniles present near the mouth and adults located from the mouth to the inner river.

The length-weight relationship parameters were statistically significant ($P < 0.05$). ANCOVA results indicated that the estimated parameters significantly differ between sexes ($P < 0.05$). Notably, all individuals larger than 56 cm TL were females, except for an individual of 70 cm TL, which was a male (Fig. 9).

Furthermore, the Student's t-test did not validate the hypothesis $\beta = 3$ ($P < 0.05$), indicating that individuals exhibited negative allometric growth in both sexes. The estimated β parameter was 2.73 (95% CI = 2.68-2.79) in females and 2.63 (95% CI = 2.57-2.70) in males.

DISCUSSION

Striped mullet in Rapel River

In the O'Higgins Region, several fishing villages, including La Boca (Rapel River), Matanzas, Puertecillo, Pichilemu, and Bucalemu, engage in small-scale fishing operations (D.Exe. MINECOM N°240-1998). However, official landings data from SERNAPESCA for 2022 only cover fish catches in Pichilemu, primarily focusing on marine species such as common hake and southern ray bream (*Brama australis*). Striped mullet ranks seventh in catch importance in this region. The selection of Pichilemu alone for sampling striped mullet by SERNAPESCA raises questions, as many fishing operations for this species are concentrated in the Rapel River, which highlights the "tyranny of the scale" problem, where marine small-scale fishing operations, such as those for common hake and southern rays bream, are closely monitored. In contrast, other species, like striped mullet, are probably underreported and significantly underrepresented in space and time. This situation underscores the value of change agents in bridging the

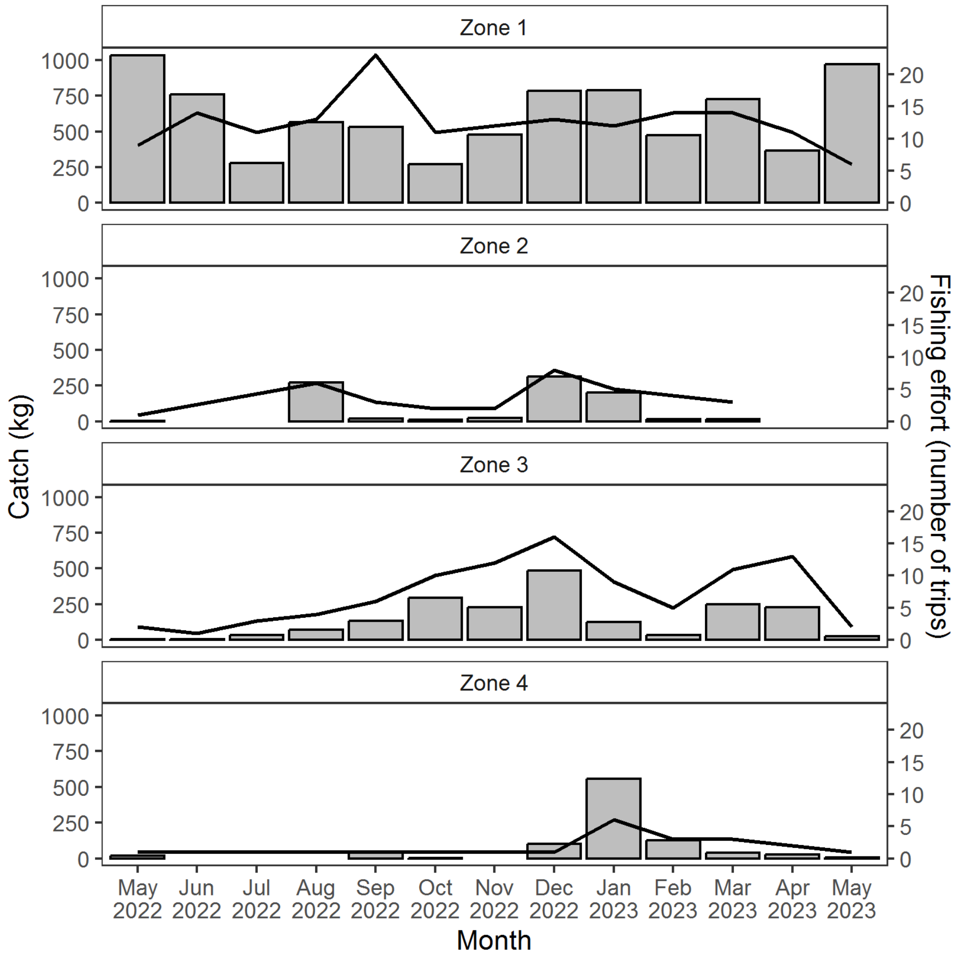

Figure 6. Temporal variations in catches (in bars) and fishing effort (in solid lines) of striped mullet by fishing zone between May 2022 and May 2023.

gap between fishers and institutions, a central element of the generic approach proposed by Prince (2010). This idea has been adapted here to address the monitoring challenges faced by small-scale fisheries in estuaries in Chile.

Approaches like the one presented in this study allow us to explore nuances in these fisheries. For example, fishers of striped mullets from the Rapel River usually use gillnets with mesh size of 3.5-4 inches. However, since December 2022, the mesh size has changed to a smaller size (2.5 inches), and we observed a progressive increment of smaller fish in the catch (<40 cm LT) and a decrease of individuals above the length at 50% maturity. Fishers expressed that they were unaware of the impact of catching smaller fish on the sustainability of the fishery, which shows the need to give constant feedback to the fishers on the effects some decisions might have on the fishery. Simple criteria are key for managing small-scale stocks (Prince 2010). In the case of striped mullets, the assessment maturity and proportion of catch below the length at 50% maturity (L50%) could be a fast and easy-to-explain criterion.

Potential foreseen drawbacks

Our proposal for monitoring small-scale estuarine fish stocks has several notable considerations and challenges. One significant aspect is the collection of samples, which, if bought, could potentially create unintended incentives for fishers. Collaboration with fisher associations is proposed to mitigate this issue. Establishing agreements on the sampling process, such as a rotating system where each fisher contributes a portion of the catch for monthly sampling, can address concerns and foster a collaborative approach. This system can also incorporate non-monetary incentives to promote sustainable fishing practices.

In our case study, the change agent faced initial challenges despite being recognized by fishers in Navidad. Some fishers were initially hesitant to provide

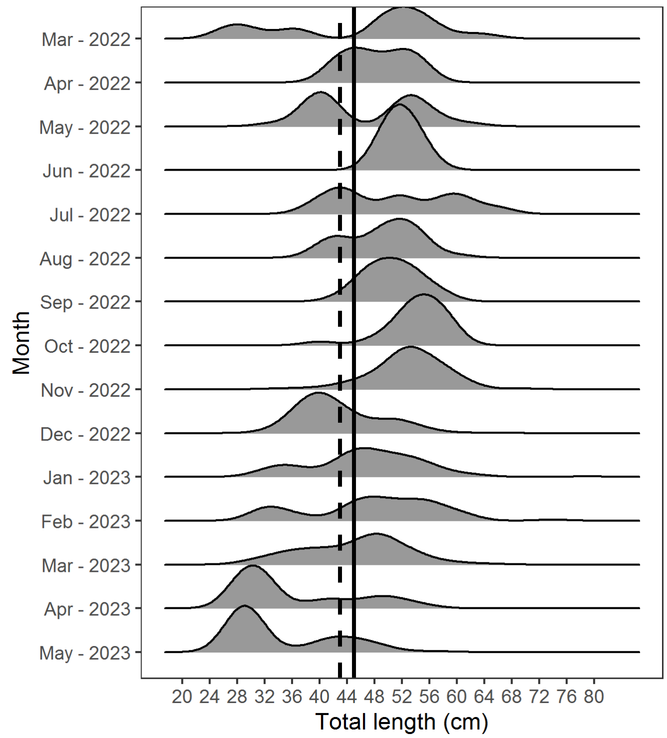

Figure 7. Monthly size structures of striped mullet in relative proportions. The vertical line corresponds to the length at 50% maturity for females (43 cm total length (TL), broken line) and for males (45 cm TL, continuous line).

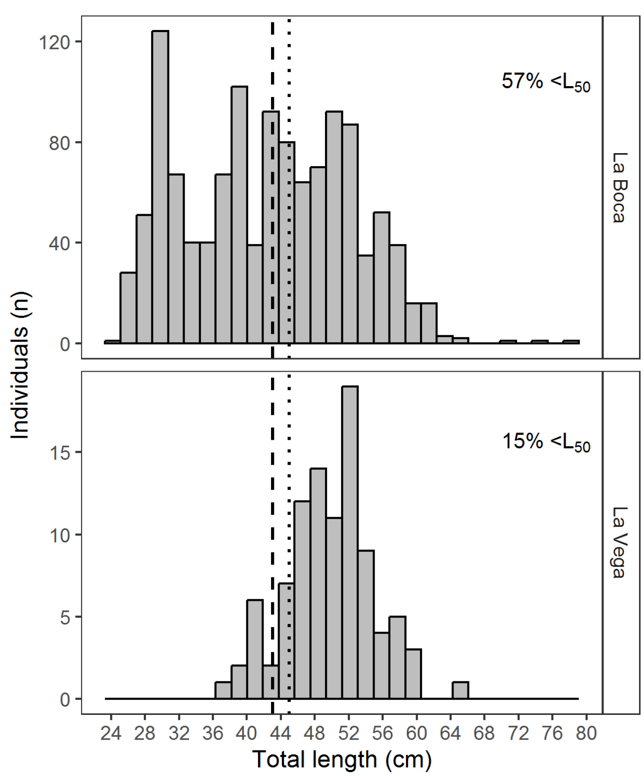

Figure 8. Relative frequency of size structure of striped mullet landed at the two main harbors in the Rapel River. The vertical line corresponds to the length at 50% maturity (L_{50}) for females (43 cm total length (TL), dashed line) and for males (45 cm TL, dotted line). The value corresponds to the percentage of individuals below L_{50}.

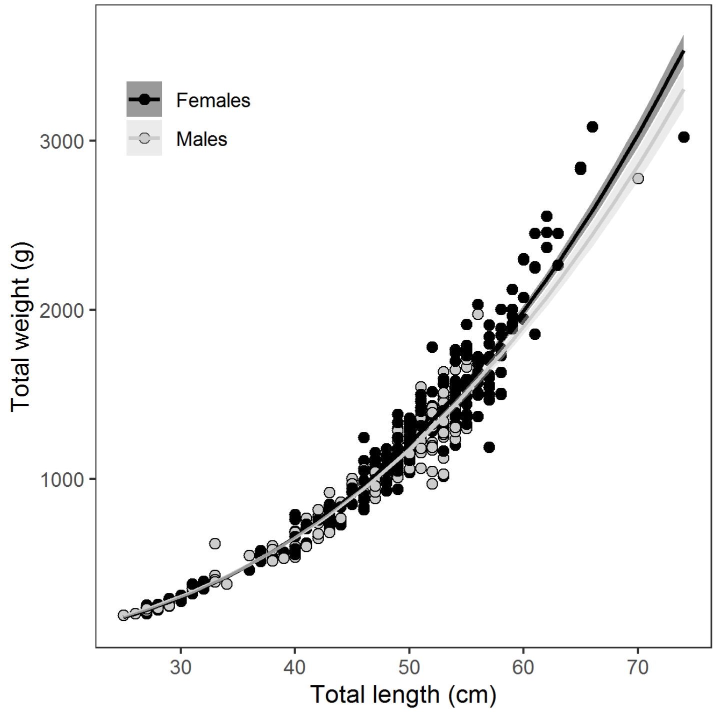

Figure 9. Length-weight relationship by sex of striped mullet. The shaded area corresponds to the 95% confidence bands.

fish for biological sampling. Addressing these concerns required building trust, socializing the pilot monitoring program, and emphasizing its focus on sustaining commercial fishing activities in the long term rather than enforcement.

Another common challenge in small-scale fisheries in Chile is the reluctance of fishers to share information, fearing that it might lead to regulatory measures such as closures, minimum landing sizes, and fish quotas. Additionally, some fishers were hesitant to lend fish for length sampling, fearing that such information could influence buyer preferences for larger sizes in the future. Overcoming these challenges involved gaining the confidence of fishers, emphasizing the mutual benefits of information-sharing for sustainable fisheries management, and clarifying that the primary goal of the pilot program was not enforcement but rather the long-term sustainability of the fishing activity.

Another anticipated challenge is associated with the funding model for fisheries research in Chile, where institutions, such as universities, often hire research assistants under self-employment schemes for annual projects funded by bodies like the Fondo de Investigación Pesquera y de Acuicultura (FIPA, Fisheries and Aquaculture Research Fund). The inherent instability of short-term contracts and self-employment arrangements poses a risk of high turnover rates among change agents. This turnover issue can lead to a continuous cycle of recruiting, training, and rebuilding trust with fishers. A potential solution is offering stable and well-paid salaries to change agents directly from the same fishing communities to address this problem. By having local change agents with stable employment, logistical costs for sampling may decrease, and the likelihood of fishers providing and sharing information could increase.

A third potential drawback of our scheme is its implicit reliance on multiple institutions throughout the country to effectively divide the space and manage estuarine stocks for cost-efficient monitoring. For instance, the logistical cost for an institution in central Chile to oversee change agents in the country's extremities would be high. Therefore, the success of our scheme depends on the involvement of institutions willing to manage change agents nationwide. However, the shortage of new generations trained in fisheries biology is a significant challenge. Only some institutions outside government agencies have fisheries scientists with the necessary training to act as coordinators and data curators for change agents. Dealing with government bodies to agree on sampling designs also requires expertise, especially in quantitative aspects of sampling design and stock assessment. This shortage of experienced fisheries scientists is common in Chile but is a global issue, including in countries like the USA (Berkson et al. 2009). Addressing this long-term problem involves investing in training programs for students and providing incentives to attract experienced fisheries biologists, particularly in remote areas of the country.

Final remarks

Our proposed monitoring scheme does not focus on developing a specific approach for collecting data on striped mullets. Instead, it presents a general framework for monitoring that can be efficiently replicated for other fisheries operating in Chilean estuaries. Species such as the Patagonian blenny, sea silverside, and naturalized chinook salmon support significant small-scale estuarine fisheries in Chile. In recent years, Patagonian blennie and sea silverside have been locally commercialized and gained popularity in major urban cities in Chile, leading to increased fishing pressure (Canales et al. 2022). These species are also targeted as bait for higher-value species like southern hake, ling (*Genypterus blacodes*), and skates (*Dipturus* sp.) in the small-scale longline fishery operating in the fjords and inner channels of Patagonia (Wiff et al. 2020, 2021). Similarly, naturalized chinook salmon targets small-scale gillnet fisheries and sport fishers in southern Chile (Sanguinetti et al. 2021).

Estuarine fisheries, such as Patagonian blennie in Chile, are particularly susceptible to changes in environmental conditions, such as river discharge (Quiñones & Montes 2001). With climate change and other anthropogenic factors like fishing exploitation and contamination, higher variability in abundance is expected. Therefore, initiating monitoring efforts for these fisheries is a crucial first step toward proposing effective conservation measures.

Our conceptual framework for monitoring acknowledges the inherent challenges posed by the “tyranny of the scale” problem. The existing data collection systems designed for large-scale fisheries and marine small-scale fisheries cannot be easily resized to accommodate the diverse characteristics of this sector. In response, our proposed framework relies on change agents to bridge the gap between local and regional management scales, addressing the biological and sociological aspects of fishing. To achieve this, trained change agents are pivotal in facilitating the necessary linkage. They are tasked with collecting biological samples from fish and conducting assessments such as macroscopic staging and extracting otoliths and internal organs, including the liver. These requirements align with the data collection standards established by scientific observers in various fisheries programs already implemented by IFOP (Bernal et al. 2012).

At the upper-level institution, the primary objective is to establish the necessary linkages between change agents and government agencies. These institutions play a crucial role in setting standards for sampling and facilitating communication between fishing communities and government bodies. Drawing from our monitoring experience in Navidad, all logbooks are seamlessly integrated with national databases for catch and effort from SERNAPESCA, vessel characteristics from SUBPESCA, and biological sampling from IFOP.

Chile boasts a robust system of unified, curated, and open-access databases for monitoring fisheries. Therefore, we recommend developing monitoring programs to merge small-scale fish information with the existing databases for large-scale fisheries. This approach ensures a comprehensive and cohesive understanding of fisheries dynamics across different scales.

This research exclusively focused on establishing a framework for monitoring small-scale fish stocks in Chile. The next steps involve assessing the exploitation states of these stocks and implementing effective management strategies. Over the last decade, fisheries scientists have developed methods for assessing data-limited fish stocks. These methods range from those based on simple biological and catch data (Zhou et al. 2013) to more comprehensive tools like FishPath (Dowling et al. 2023) designed for effective fisheries management.

Chilean fishing law aligns with the precautionary approach for fisheries management, emphasizing that the lack of information should not be a reason to postpone or neglect management measures to conserve small-scale fish species in Chile. Monitoring these stocks represents the initial step toward conservation, and discussions on implementing effective monitoring measures can no longer be delayed. This research significantly contributes to this discourse, demonstrating the viability of our conceptualization in the context of striped mullet. It underscores that a cost-efficient monitoring system for small-scale estuarine fish stocks is not only possible but imperative. Our conceptualization relies on change agents and experienced fisheries scientists outside government agencies, with active participation from fishers. Decisions are guided by a continuous feedback loop involving authorities, institutions, change agents, and fishers.

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