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Research Article

A pilot tagging program on southern rays bream (*Brama australis*): methodology and preliminary recaptures

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ABSTRACT. The southern rays bream (*Brama australis*) is a highly migratory, epi-mesopelagic species supporting an important artisanal fishery off central-southern Chile. Despite its importance, several questions exist about this species's demography and migratory routes. The first step in understanding the migratory behavior of *B. australis* is to test the feasibility of a conventional tagging program, a standard mark-recapture method, to infer migration in fish. Between February 2020 and December 2021, conventional tagging was conducted during 21 fishing trips on board artisanal vessels off Lebu harbor (Biobío Region, Chile) using gillnets, longlines, and handlines. Three thousand nine hundred forty-six individuals of *B. australis* between 30 and 55 cm fork length were tagged using external T-anchor bar labels (commonly known as "spaghetti"). Approximately 100 and 200 fish were tagged per fishing trip using longlines and gillnets, respectively. The size distribution of the tagged individuals was consistent with those retained in the catch, with 90% of tagged fish being longer than the fork length at 50% maturity. Eight tags have been recovered off the coast of Lebu up to May 2022. With times at liberty between 50 and 537 days. These preliminary recaptures are also analyzed in the context of the conceptual model for demography and migration proposed for this species in Chile. The main conclusion of this research is that a conventional tagging program is feasible for *B. australis* in Chile.

Keywords: *Brama australis*; southern rays bream; tagging program; artisanal fishery; migratory fish; South Pacific

INTRODUCTION

The southern rays bream *Brama australis* (Valenciennes, 1838) is an epi-mesopelagic species distributed in the South Pacific off Chile and New Zealand coasts. In Chile, this species is mainly found between 100 and 500 m deep and over a wide latitudinal range from the central zone (27°S) to southern Patagonia (57°S), including the inshore waters of Chiloé Island (San Martín et al. 2017). Despite this extensive distribution, recent stock discrimination studies determined a single population of *B. australis* in Chile (Galleguillos et al. 2015, Oliva et al. 2016).

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Around 90% of *B. australis* catches are reported by artisanal boats (~8 m length) and small-scale vessels (~14 m length), alternating gears between longlines and gillnets depending on the location of the shoals in the water column. Official landing records are relatively new, starting in 1994 with artisanal fishing operations in the central zone off Coquimbo and Valparaíso regions. From 2000 onwards, fishing activi-ties moved southward, and catches increased rapidly. More recently, most landings come from the Lebu harbor, with catches of about 39,000 t in 2021 (Gálvez et al. 2022) In 2008, industrial mid-water trawlers started reporting target catches of *B. australis*, mostly in northern Patagonia between 43 and 47ºS (Canales et al. 2014).

Despite the importance of *B. australis* for artisanal fishermen in central regions of Chile, there are many knowledge gaps in their basic biology and population dynamics. Its growth is relatively slow, with no sexual dimorphism and a lifespan between 9 and 12 years (Leal 2019). *B. australis* also has a narrow trophic spectrum, eating mostly krill (*Euphausia mucronata*), and occasionally cephalopods, small fishes (Muñoz et al. 1995, García & Chong 2002), stomatopods (*Pterygosquilla armata*) and hyperiid amphipods (Santa Cruz et al. 2014). Based on histological analyses, the reproductive biology of this species was characterized as asynchronous with indeterminate fecundity and winter batch spawning with a long maturity period (Leal & Oyarzún 2003). The main spawning area is unknown, although Pavlov (1991) reported individuals close to spawning during winter-spring in the South Pacific oceanic waters. In this context, Pavlov (1994) hypothesized migratory patterns where spawning takes place in oceanic waters. This migratory hypothesis was then extended by Leal & Oyarzún (2003), who proposed a conceptual model with large-scale migrations in which *B. australis* feed, grow, and mature in Chilean coastal waters but spawn in oceanic waters. This conceptual model is common to other exploited species in Chile, such as jack mackerel, *Trachurus murphyi* (Parada et al. 2017) and swordfish (*Xiphias gladius*) (Gatica et al. 2009). However, given the lack of *B. australis* migration studies and the lack of interest of Chilean vessels in fishing for this species in oceanic waters beyond the jurisdictional zone, the underlying migration hypo-thesis has not yet been tested.

Fish species showing large-scale migratory behavior with unknown spawning areas pose big challenges for management. While registering new vessels for fishing *B. australis* in Chile is currently closed, and its incidental capture is rare (e.g. alongside common hake *Merluccius gayi*), management still needs to include the application of annual quotas. Stock assessment of this species considers catch-based, data-poor methods for estimation, given the lack of reliable abundance indices or catch-at-age information (Leal 2019). Conceptualizing the population dynamics and collecting associated data is key to sustainable management. In particular, understanding their migratory routes is needed for managing fishing resources, including quota allocations, amongst other administrative management actions.

The study of migratory species worldwide is commonly based on tagging procedures. Studies on small pelagic fish are usually conducted using conventional tags, such as the T-bar or Dart tag (e.g. *Clupea harengus* (Nakashima & Winters 1984)). In contrast, in highly migratory large pelagic fish studies, electronic tags such as pop-ups are more common (e.g. *Thunnus alalunga* (Cosgrove et al. 2015)). However, while electronic tags remain unaffordable in many parts of the world, conventional tags are relatively cheap and fast to implement, allowing the tagging of a large number of individuals. Despite the popularity of tagging programs globally, the Chilean tagging of commercial teleost fishes is limited to a few species and is fragmented in time. To date, Chilean tagging of pelagic fishes is restricted to anchoveta, *Engraulis ringens* (Martínez et al. 1998), common sardine, *Sardinops sagax* (Torres et al. 1985), jack mackerel (Torres et al. 1986), and swordfish (Barría et al. 2016, Zárate et al. 2019). In demersal species, tagging has been applied to common hake (Villegas & Saetersdal 1968) and Patagonian toothfish *Dissostichus eleginoides* (Rubilar et al. 2013, 2014). Currently, the only established tagging program in Chile is conducted on swordfish by the Instituto de Fomento Pesquero (IFOP) since 2005. Teleost fish stocks in Chile are highly abundant, especially in pelagic species, with individuals migrating over several kilometers of coastline and crossing administrative regions where they are exploited by different fishing gears operated by artisanal, small-scale, and industrial vessels. These features, combined, impose great challenges for a successful tagging program, especially at the tag-recovery level. Ensuring adequate recapture numbers of tagged fishes relies on tagging large numbers of individuals, with the added logistical challenge of an effective recapture advertising campaign across vast regions and remote communities. Given the importance of *B. australis* for the artisanal fishermen off the coast of central Chile, an adequate understanding of the conceptual model, including the migratory behavior, is warranted. Therefore, the main aim of this study is to test the feasibility of a conventional tagging program for *B. australis* in Chile. The results of this pilot tagging program are presented with recommendations for its implementation based on artisanal vessels fishing over an extensive area.

MATERIALS AND METHODS

Tagging protocol

A recent literature review by Wiff et al. (2022) for medium-body pelagic species found that the most common tag used is the T-anchor bar, commonly known as "spaghetti" (model FD-94, Floy Tag & Mfg. Inc., Fig. 1a).

This kind of tag was selected for use in *B. australis* because they allow for fast and plentiful tagging of fish through reduced manipulation time and are easy to detect in the catch given the color contrast between fish and tag.

A laboratory experiment was conducted to train scientific observers in a tagging protocol. A Pistol Grip-type tagging system was used to insert the tag (Fig. 1b). Different positions along the dorsal fin were selected for the attachment of the tag in 10 individuals of *B. australis* bought in the local market. The fish were dissected to assess the most suitable place to attach the tag. The space between the third and fourth radii of the dorsal fin was chosen for tagging *B. australis*. In this area, the rays are larger and have narrower gaps between them, enabling a firm and secure tag attachment (Fig. 1c). An image of this tag and application to *B. australis* is shown (Fig. 1d).

The tagging protocol included measuring the fork length (FL) to the nearest centimeter, annotating the tag unique code number, and releasing the tagged fish from the opposite side of the fishing retrieval operation. Tags were checked as firmly attached before release, and those with poor attachments were retained in the catch. Fish selected for tagging needed to be alive, with no visible external damage such as mouth bleeding, abrasion, and scales loss. Once the fishermen provided the live fish to the scientific observer, the tagging process was fast, taking between 10 and 20 s until release. Scientific observers also annotated in logbooks the fishing operation characteristics, such as the start/end position of the fishing line, type of gear, depth of fishing, total catch per fishing trip, bycatch by species and number, and counts of marine mammals during the retrieval.

A random sample of up to 100 individuals of *B. australis* from the catch of each fishing trip was measured, along with an additional maximum of 50 individuals both measured and weighed (TW, total wet weight to the nearest gram). The estimated parameters were compared using an analysis of covariance (ANCOVA). The length-at-weight relationship was computed to evaluate differences in condition factor between seasons and fishing gears using the power function $TW = \alpha FL^{\beta}$, where α and β are growth parameters. Condition factor per season and gear type was also computed as the ratio between TW and αFL^{β} and was used as an indirect measure of the nutritional status of fish (Froese 2006).

In commercial fishing operations, the sampling protocol included recording the size structure of a random sample of the retained catch to evaluate the size overlap between tagged and retained catches, also known as "tag-size overlap". It is an important diagnostic in tagging programs, as the size structure should match to produce unbiased estimates of population parameters and spatial movements from the tags.

Tagging program implementation

As previously described, around 70% of the *B. australis* catch currently comes from artisanal operations from the Lebu harbor in the Biobío Region (37º36'S). Therefore, we chose this area as an operation center for a pilot tagging program for *B. australis*. Tagging was conducted opportunistically between February 15, 2020, and December 21, 2021, with several gaps given the restrictions on the movements and embarkments of scientific observers due to the Covid-19 pandemic. The first two fishing trips were experimental and for tagging protocol refining. The first experimental trip was exclusively for refining the sampling protocol and was conducted using handline on an artisanal boat close to the coast with three scientific observers. The experience in this first trip demonstrated that the tagging of *B. australis* can be fast and efficient when conditions are good. The second tagging experiment was on board an artisanal small-scale gillnet vessel in March 2020 with a crew of five fishermen and two scientific observers. Given the long soaking times commonly applied by small-scale gillnet vessels (10 h on average), a very low percentage of fish (1.8%) were in a condition that passed the criteria to be tagged. From the third fishing experience onwards, tagging was conducted in 8 m artisanal boats alternating between handlines, longlines, and gillnets and able to host one scientific observer. A total of 21 fishing trips were con-

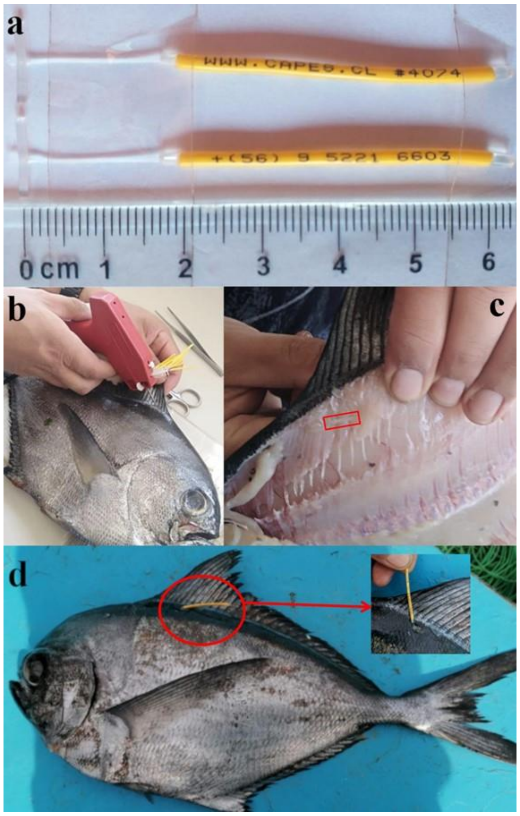

Figure 1. Tagging of a southern ray bream fish (*Brama australis*): a) T-anchor bar tag indicating information for recovery; b) tagging system Pistol Grip; c) a tag T-anchor located between the third and the fourth fin rays of the dorsal fin. The red rectangle shows the tag base; and d) a recovered individual with the tag.

ducted, comprising 17 commercial fishing trips and four specifically for tagging. Fifty-one fishing hauls were conducted on board artisanal and small-scale fishing vessels equipped with handline, longlines, and gillnets.

Recovery tag program

We developed an intensive information program aimed at fishermen to maximize tag recovery. A web page with information for the tagging program was developed, and posters and leaflets were designed and produced for dissemination in landing ports (Fig. 2b), supermarkets, local shops frequented by fishermen, a local radio station, and a TV program. Advertising of the tagging program took place between Valparaíso and Quellón, according to the main landing harbors of this species (Fig. 2a). A series of meetings also took place with fishermen's associations to explain the project aims. Fishermen and IFOP scientific observers from the industrial fleet targeting *B. australis* in the austral zone off Chile were also informed about the tagging program. Scientific observers also regularly accessed the landing operation in Lebu harbor, searching for tagged fish in the reported catches. Incentives to recover tags were designed especially for the program. They included custom t-shirts, sets of fishing knives, and acknowledgment letters with a mapped location and date of the recovered tag. Monetary rewards for tag recovery were not allowed by the Undersecretariat of Fishery (SUBPESCA, by its Spanish acronym) in any tagging program developed in Chile.

RESULTS

Tagging program implementation

During the first tagging experiment, 27 individuals of *B. australis* were caught using handline, from which 23 were in suitable conditions for tagging (88% survival rate). Allowing for refinement of the sampling protocol where *B. australis* can be tagged "on dry", meaning there was no need for onboard tanks for acclimatization. The total catch in this fishing trip was 4920 individuals of *B. australis*, from which 104 were in good condition for tagging (2% survival rate).

Given the complexity of the fishing operations in small-scale vessels, the remaining tagging trips were performed onboard artisanal boats from Lebu. A total of 3946 individuals of *B. australis* were tagged, ranging from 30 to 55 cm FL. The fishing gear was alternated between horizontal longlines and gillnets, with handlines only used occasionally by fishermen and scientific observers to increase the number of fish in good tagging condition (Table 1). The longline proved less efficient than gillnets in providing fish for tagging, as longlines are retrieved by winch, meaning a stoppage of operations when unhooking fish for the scientific observers. An average of 100 individuals per trip were tagged in commercial longline operations. On average, 200 individuals per trip were tagged in commercial gillnet operations. Gillnets provide potentially large numbers of fish, but only when soaking time is short (between 2 and 4 h) such that the fish are in good condition for tagging.

Most tagging took place around the Mocha Island off Lebu harbor, and some hauls off Talcahuano during the spring of 2021 (Fig. 3a). A few hauls were also conducted southern Lebu harbor during the spring and summer of 2020. The sampling protocol specifies counting marine mammals during tagging for their potential effect on the tagging program. Only sea lions (*Otaria flavescens*) were found in 20 fishing hauls (36%), usually close to the coast, and with a higher frequency during the spring of 2021 off Lebu harbor

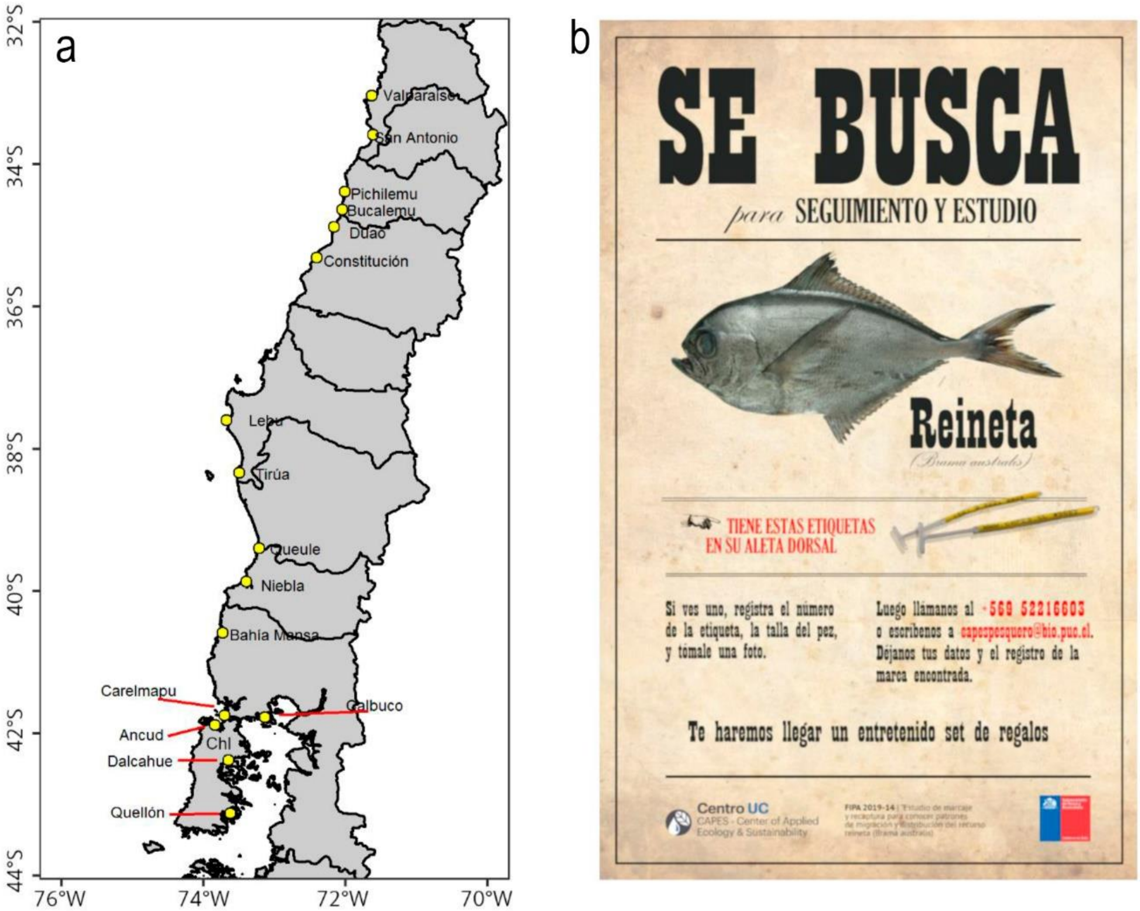

Figure 2. a) Main landing ports visited, and b) the original poster/leaflet (in Spanish) used for the dissemination program. ChI: Chiloé Island.

(Fig. 3b, Table 1). In general, sea lions do not present a potential problem for a *B. australis* tagging program.

A total of 1499 *B. australis* from the retained commercial fishing catches were measured, ranging from 28 to 52 cm FL (mean = 41.6 cm). The size structure of tagged *vs*. retained individuals completely overlapped and showed a symmetric and unimodal distribution (Fig. 4). There was no significant difference between the size structures of tagged and retained fish (P = 0.637). In addition, 88% of retained and 90% of tagged fish were bigger than the length at 50% maturity of 37.7 cm FL (Fig. 4).

From the retained catch, 849 fish (56.6%), ranging between 31 and 53 cm FL and between 450 and 2780 g TW were also weighed. Parameters of the length-at-weight relationships were significant over both seasons and fishing gears (P < 0.05). Fish caught using longlines in spring had a wider size range (31-50 cm FL) and presented higher numbers of individuals smaller than 35 cm FL compared to fish caught during the summer with longlines (35-53 cm FL) and gillnets (36-50 cm FL, Fig. 5).

Positive allometry ($\beta > 3$) was found in fish caught using longlines during spring. In contrast, negative allometry ($\beta < 3$) was reported for fish caught with gillnets during summer. The ANCOVA test indicated significant differences among the estimated parameters by fishing gear (P < 0.05). These differences were attributable to individuals caught using longlines during spring. The condition factor did not vary significantly among seasons and fishing gears (P > 0.05), with values around 1 (Fig. 5). Collectively, these results suggest the biological condition of all tagged fish to be similar during the study period.

Bycatch in commercial fishing operations was relatively low and negligible for longlines. A small amount of bycatch was recorded in gillnet fishing operations, where the most common species were jack mackerel (*Trachurus murphyi*), hoki (*Macruronus magellanicus*), snoek (*Thyrsites atun*), and jumbo squid (*Dosidicus gigas*) (Table 2). Large sharks were also reported in the tagging fishing hauls, with records of 45 blue shark (*Prionace glauca*) and 24 mako shark

Table 1. Summary of the fishing operations for *Brama australis* tagging by year and season. SD: standard deviation.

Year	Season	Tagging logbook Vessels n	Trips n	Hauls n	Fishing gear	Tagged fish n	Fork length (cm) Range	Mean (SD)	Sea lions n
2020	Summer	1	2	2	Gillnet	103	31 - 47	41.8 (2.28)	2
				3	Handline	41	37 - 51	42.0 (3.01)	
	Spring	2	2	5	Longline	90	31 - 44	35.8 (3.10)	3
2021	Summer	2	10	9	Both	1144	31 - 55	43.4 (2.19)	1
				4	Both	78	34 - 44	37.3 (2.29)	
	Spring	2	7	1	Gillnet	208	31 - 44	39.0 (2.07)	14
				13	Longline	695	30 - 52	40.7 (3.46)	
				15	Longline	1607	33 - 50	41.6 (2.92)	

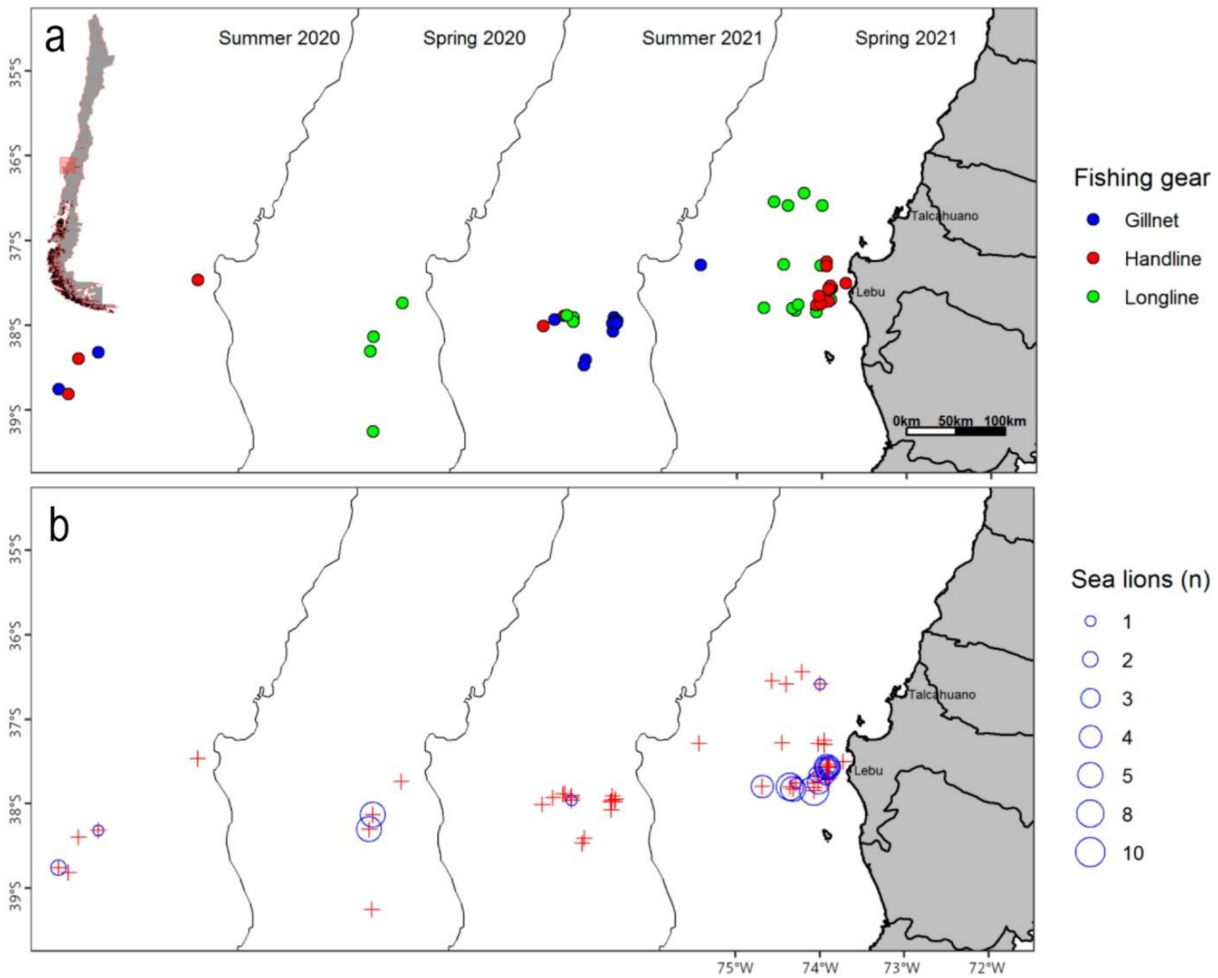

Figure 3. a) Location of fishing hauls (points) by season and fishing gear, and b) the number of sea lions (*Otaria flavescens*) counted during tagging (in circles) and location of fishing hauls (in crosses). Lines on the maps show the administrative regions in Chile. The red square on the left side map (upper panel) indicates the location of the study area concerning the country's extent.

(*Isurus oxyrinchus glaucus*) (Table 2). Seasonal changes in the bycatch were observed, with hoki commonly observed in spring and jack mackerel and jumbo squid in summer (Table 2).

Table 2. Bycatch from commercial fishing operations during the tagging trips for *Brama australis*.

Year	Season	Class	Common name	Specie	Number	Frequency (%)
2020	Summer	Actinopterygii	Jack mackerel	*Trachurus murphyi*	137	68.8
			Patagonian toothfish	*Dissostichus eleginoides*	1	0.5
			Horse marckerel	*Scomber japonicus*	18	9.0
			Tuna	*Allothunnus fallai*	2	1.0
			Sunfish	*Mola mola*	1	0.5
		Cephalopoda	Jumbo squid	*Dosidicus gigas*	15	7.5
		Chondrichthyes	Blue shark	*Prionace glauca*	20	10.1
			Mako shark	*Isurus oxyrinchus glaucus*	5	2.5
	Spring	Actinopterygii	Hoki	*Macruronus magellanicus*	15	100.0
2021	Summer	Actinopterygii	Hoki	*Macruronus magellanicus*	3	0.5
			Jack mackerel	*Trachurus murphyi*	460	83.2
			Snoek	*Thyrsites atun*	1	0.2
			Luvar	*Luvarus imperialis*	1	0.2
			Butterfly kingfish	*Gasterochisma melampus*	4	0.7
			Tuna	*Allothunnus fallai*	2	0.4
			Flatfish	-	2	0.4
		Cephalopoda	Jumbo squid	*Dosidicus gigas*	37	6.7
		Chondrichthyes	Blue shark	*Prionace glauca*	25	4.5
			Mako shark	*Isurus oxyrinchus glaucus*	18	3.3
	Spring	Actinopterygii	Hoki	*Macruronus magellanicus*	82	76.6
			Jack mackerel	*Trachurus murphyi*	10	9.3
			Snoek	*Thyrsites atun*	14	13.1
		Chondrichthyes	Mako shark	*Isurus oxyrinchus glaucus*	1	0.9

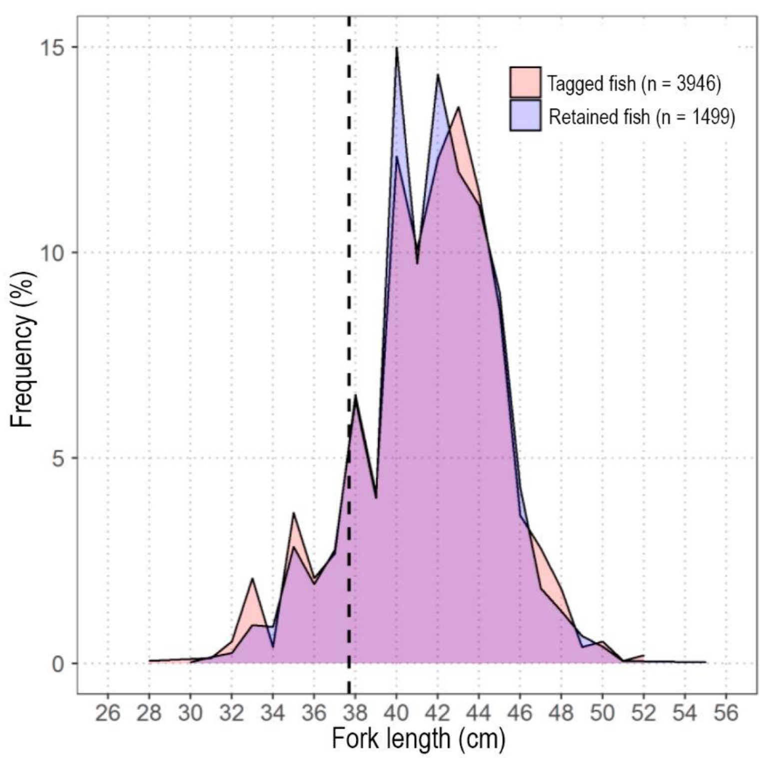

Figure 4. Comparison of the size distributions of tagged *vs.* retained individuals in the catch of *Brama australis*. The vertical dotted line indicates the length at 50% of maturity (37.7 cm fork length, Leal et al. 2017).

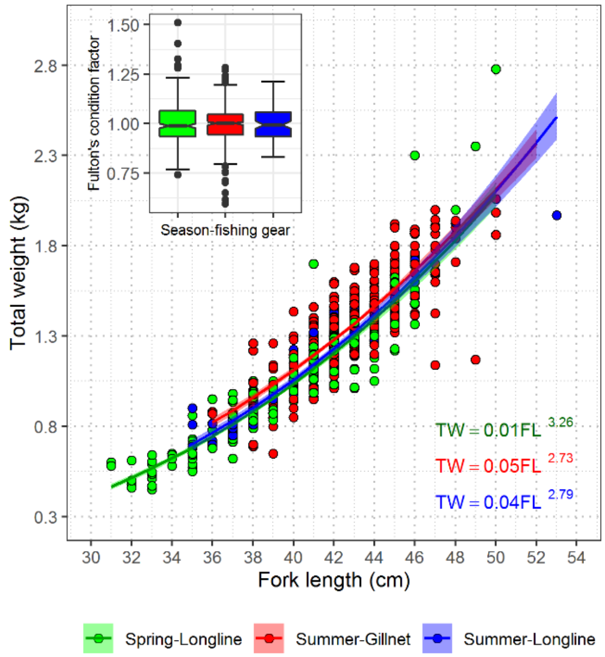

Figure 5. Length-at-weight relationship ($TW = \alpha FL^{\beta}$) estimated and Fulton's condition factor by fishing gear and season from the retained catch. Dots indicate the observations and the shaded area at the 95% confidence intervals.

Recovery tag program

The dissemination program was well received by fishermen, which were often very curious regarding the migration cycle of *B. australis*. There were also very up to inform any tag recovery, and they often exchanged telephone numbers and other contact details with our scientific observers. Up to May 2022, eight tags have been recovered, six from gillnets, one from handline, and one from longline (Fig. 6).

All recaptures occurred within the fishing area off Lebu harbor, with time at liberty ranging from 50 to 537 days. Sizes between 41 and 51 cm FL (Fig. 7). Four individuals (#tags 14, 483, 659, and 1179) were recovered in offshore waters and at a distance greater than 40 km from the point of tagging. Fish with #tag 137 was recovered at 9 km from the tagging point (Fig. 6). The recovery rate of individuals (recaptured fish *vs.* tagged fish released at the time of recovery) with more than a year at liberty (n = 4) was 2%. In contrast, for more recently tagged fish (n = 4, less than a year at liberty) was 0.3%.

DISCUSSION

A tagging program for *B. australis* in Chile imposes great challenges given its large population size, extensive geographic distribution, exploitation by several fleets, and varying fishing gears. For instance, this implies that many fish must be tagged to obtain sufficient recoveries to infer migration routes. Thus, the T-anchor bar was favored because it was proven fast (between 10 and 20 s) for tagging *B. australis*. Additionally, being easily visible and clearly labeled for fishermen and other stakeholders increases the chances of tag recovery. These tags can also be applied "on dry", for which no acclimatization tanks are needed, saving time and space onboard artisanal boats. Our laboratory experience also confirmed that the T-anchor bar could be firmly attached to the longest radii of *B. australis*. The secure attachment of external tags is of great importance, as tag loss is a common problem in tagging programs, potentially adding bias in estimated population parameters (Björnsson et al. 2011).

A tagging program for this species should be based mainly on artisanal boats, as the characteristics of their operation lead to fish in good conditions for tagging. Favorable weather conditions for operating artisanal boats in central-southern Chile become narrow-window periods year-round. However, they are particularly short during autumn and winter. A tagging program needs at least two scientific observers with the exclusive task of tagging on-call during these favorable weather windows. However, more than favorable weather conditions are needed to guarantee a successful commercial fishing operation -as with many migratory species, *B. australis* have large variations in their spatiotemporal dynamics. As such, their distribution can change rapidly from coastal to offshore, shallower to deeper water, adding extra complexity to fishing operations, and by extension, to the success of any associated tagging program. For example, when *B. australis* is far from the shore, artisanal boats swap fishing efforts towards coastal jumbo squids (*Dosidicus gigas*). These commercial fishing logistics must be accounted for in developing a successful Chilean tagging program.

Despite these operational challenges, a Chilean *B. australis* tagging program is feasible. We recommend that the tagging program be developed on artisanal boats that yield adequate numbers of tagged fish per fishing trip. The number of fish tagged in artisanal boats was 100 and 200 per fishing trip using loglines and gillnets, respectively. On the other hand, small-scale vessels have more autonomy with longer fishing trips and fishing volumes, but given the usual long soaking times (~10 h), most fish caught are dead or not in good condition to be tagged. Our experience indicates that *B. australis* generally have a low survival

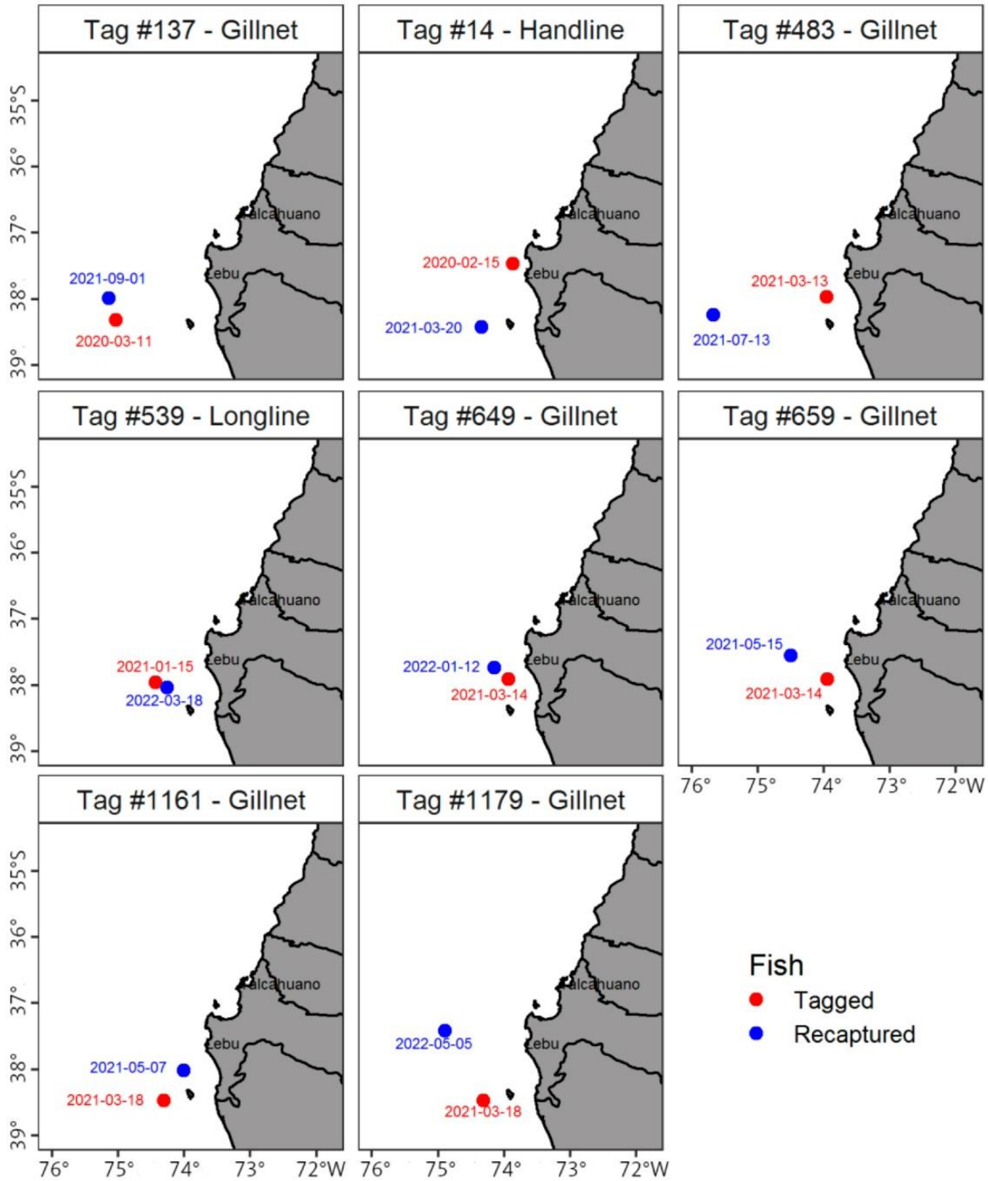

Figure 6. Location and date of tagging and recapture. Each plot title indicates the tag number and fishing gear used for tagging. Lines on the maps show the administrative regions in Chile.

rate even when released in good condition; using handlines, individuals only survived for up to 30-90 min in specially prepared onboard tanks equipped with oxygenators. In normal fishing operations, however, most of the catch is already dead when retrieved onboard, especially in small-scale vessels, which implies that fishermen's cooperation is crucial to conducting a tagging program on *B. australis*. In our case, one haul per fishing trip was usually designated for tagging, with a shorter soaking time (<4 h) and fish being carefully treated when retrieving to maximize survival.

Tagging experiments for teleost fish stocks in Chile are few and fragmented. In pelagic species, there are tagging experiences in anchovy (Martínez et al. 1998), common sardine *anchovy* (Torres et al. 1985), jack mackerel (Torres et al. 1986), and swordfish (Barría et al. 2016, Zárate et al. 2019). Demersal species tagging experiments are similarly rare, having been conducted for common hake (Villegas & Saetersdal 1968) and Patagonian toothfish (Rubilar et al. 2013, 2014). Currently, the only teleost tagging program is for swordfish. According to the review by Wiff et al. (2022), conventional tags provide an average recovery

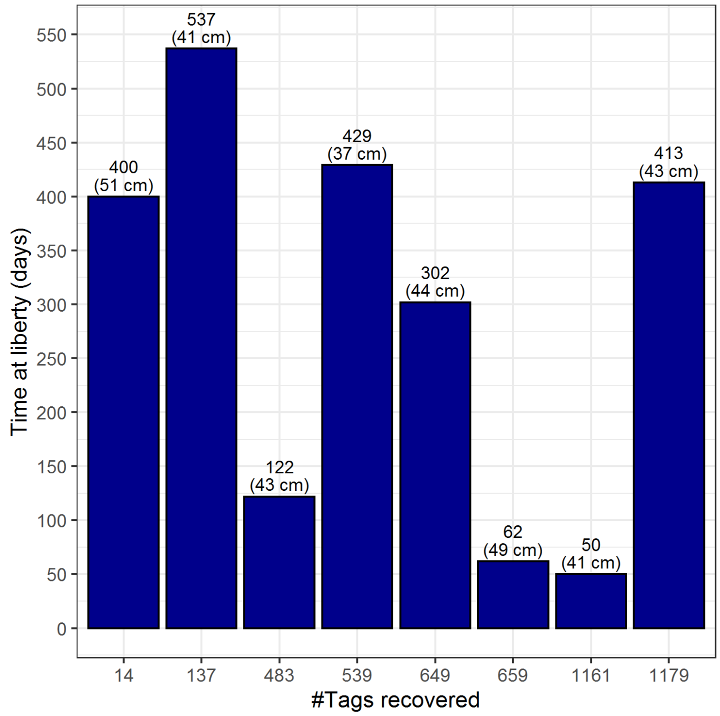

Figure 7. Times at liberty (days) for each of the recaptured fish. Fork length recorded when individuals were tagged shown in brackets.

percentage of 4 and 8% for pelagic and demersal fish, respectively. In the Chilean stocks, the recovery percentage has been lower, ranging from 0.5 to 3.4% in pelagic species using conventional internal tags (metal tags) or external (e.g. T-anchor bar or Billfish tag). Tag recovery increases in demersal species, ranging from 1.1 to 7.4%. The main causes of low tag recovery in Chile are many and stock-dependent. Difficulties in detecting metal tags in processing plants are suggested as the main cause for the poor tag recovery in small pelagic fish in Chile (Martínez et al. 1998). For common sardines, tagging trauma on such small fish may increase mortality (Torres et al. 1985). In the case of jack mackerel, species distribution changes may cause low numbers of recovered tags (Torres et al. 1986). For demersal species, such as common hake, individuals are usually dead when retrieved due to changes in pressure and abrasion in trawling nets. Thus, the few fish alive and tagged may have very low chances of surviving (Villegas & Saetersdal 1968).

B. australis is one of the most important fish resources for the artisanal fisheries operating in central-southern Chile. Despite its importance, substantial knowledge gaps exist regarding this species's fundamental biology and distribution. However, there is a single stock unit off the coast of Chile (Galleguillos et al. 2015), with a latitudinal gradient in size distribution (Gálvez et al. 2018) and unknown spawning areas, which supports the hypothesis that *B. australis* is a highly migratory species. In this context, Leal (2019) proposed a conceptual model for the migration patterns of *B. australis* in the southern Pacific. This conceptual model proposes that spawning areas are located in oceanic waters in the south Pacific in autumn, followed by recruitment in southern Chile during winter, and feeding and growth during spring and summer off the coast of Lebu. Other studies support this conceptual model. Pavlov (1994) proposed an oceanic spawning in *B. australis* based on observing spawning females. Leal (2019) adopted this idea also based on the lack of observations of females close to spawning (hydrated), recently spawned (post-ovulatory follicles), or spent in the coastal areas of Chile (Leal & Oyarzún 2003, Leal et al. 2017). However, Pavez et al. (1998) collected hydrated females between 10 and 40 nm off the coast of the Valparaíso region in central Chile during autumn and spring, which suggests that the main spawning area may be oceanic, but also with some minor patches of spawning activity in coastal areas of Chile. The oceanic spawning hypothesis is also supported by the presence of larval stages of *B. australis* in oceanic water masses associated with Rapa Nui (Easter) Island, Salas and

Gómez islands (Castro & Landaeta 2002), Juan Fernández Archipelago, and San Félix and San Ambrosio islands (Acuña et al. 2009).

An oceanic spawning of southern rays bream implies a large-scale migratory process similar to that proposed for jack mackerel, with a hypothesized oceanic spawning area between (35-37.5°S, 112-116.5°W) associated with oceanic seamounts (Parada et al. 2017). Seamounts also characterize the proposed spawning area for *B. australis* (Pavlov 1994) in the south Pacific (42-47°S, 105-127°W). Oceanic seamounts are areas characterized by vertical fluxes of nutrients and organic matter, which enhance the productivity and survival of the early stages of fish (Parada et al. 2017). This oceanic migration of *B. australis* can be inferred from catches of this species which converge around 40°S and then become more oceanic (San Martín et al. 2017). This behavior is supported by our preliminary recapture results, in which some of the recaptured fish were found offshore (from 53 to 104 km) from their tagging location. Fishermen argue that they harvest the shoal of fish as it moves until the vessel's carrying capacity is reached, and then the shoal moves to offshore areas. This shoal behavior may explain the lack of recaptures in the same fishing trip or the following few days by other nearby fishing vessels ("within-season recapture"), which is otherwise common in tagging programs. In addition, most recaptures occurred with fish over a year at liberty, with only a few more recently tagged fish.

Additionally, recaptures were not reported in all the remaining localities or harbors that operate on this resource, distributed between 32 and 43°S, despite the intensive dissemination program implemented. These preliminary observations support the hypothesis of an oceanic migration but also provide insights for the recommendation for a tagging program in *B. australis*. The implication is that a tagged fish may migrate seasonally to oceanic water to complete a reproductive cycle, so it is expected that a year passes before a potential recapture occurs in the same area. First, a long-term tagging program should be implemented given this migratory hypothesis, and recaptures may be expected on a year-level timeframe. Second, tagging should be extended to other areas, particularly north and south of Lebu harbor, to infer any coastal movements. Third, a tagging program should also collect data on feeding and maturity state to investigate the drivers of migratory behavior in *B. australis*. Fourth, bycatch also should be quantified as other species in the catch will provide insights for understanding the migratory behaviors of *B. australis*. The investigation provides the methodological bases for an effective tagging program of *B. australis* as the first step in developing a national mark-recapture program for this highly migratory species.

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