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International Journal of Fisheries and Aquaculture

Full Length Research Paper

Preliminary report on "two spot" razor fish, *Iniistius bimaculatus* (Ruppell, 1829) found in the Chennai coastal waters, southeast coast of India

K. Silambarasan[1]*, K. Sujatha[2], A. Sundaramanickam[3] and E. Rajalakshmi[1]

[1]P.G. and Research Department of Zoology, Sir Theagaraya College, Chennai, India.
[2]Dr. M.G.R. Educational and Research Institute (University), Chennai, India.
[3]Centre of Advanced Study in Marine Biology, Faulty of Marine Sciences, Annamalai University, Parangipettai, India.

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The present study reports the first occurrence of two spot razor fish, *Iniistius bimaculatus* (Ruppell, 1829) from the Chennai coastal waters, Southeast coast of India. Two specimens measuring 141 mm and 169 mm TL was collected from trawl catches in the Chennai coast during September 2010. A systematic account of this species and a description, colour and notes on its distribution is provided. The controversy of two similar genus *Iniistius* and *Xyrichtys* were discussed.

Key words: Two spot razor fish, *Iniistius bimaculatus*, trawl catch, Chennai coast.

INTRODUCTION

The family Labridae (the wrasses), comprises about 68 genera and at least 600 species. It is the eleventh largest vertebrate family and second largest marine fish family (Parenti and Randall, 2000), it is among the most morphologically and ecologically diversified families of fishes on coral and rocky reefs. The genus *Iniistius* (Gill 1862) is represented by 19 species that typically inhabit Atlantic, Indian and Pacific waters, Red Sea, Persian Gulf and New Guinea (Frose and Pauly, 2012; Eschmeyer and Fong, 2012). The systematic account of the genus *Iniistius* and *Xyrichtys* have not been studied in details. The genus *Iniistius* have been considered synonyms of Xyrichtys by some authors. Randall and Earle (2002) reclassified this species after Tri-thuc (Nguyen, 1974) who distinguished the two genera and discovered they are separated osteologically. Externally, the two genera can be distinguished by the following characters:

1. The palatine bone overlaps the ectopterygoid in *Iniistius*, where as it is separate in *Xyrichtys*;
2. There are no dorsal pterygiophores between the second and third neural spines of *Iniistius* but two in *Xyrichtys*.
3. The skull is notably higher in adult *Iniistius* than in *Xyrichtys* .
4. The position of the origin of the dorsal fin is over or less than half an orbit diameter behind the eye in *Iniistius*, but more than an eye diameter behind the eye in

*Corresponding author. E-mail: silambuplankton@hotmail.com. Tel: +91 9962471352.

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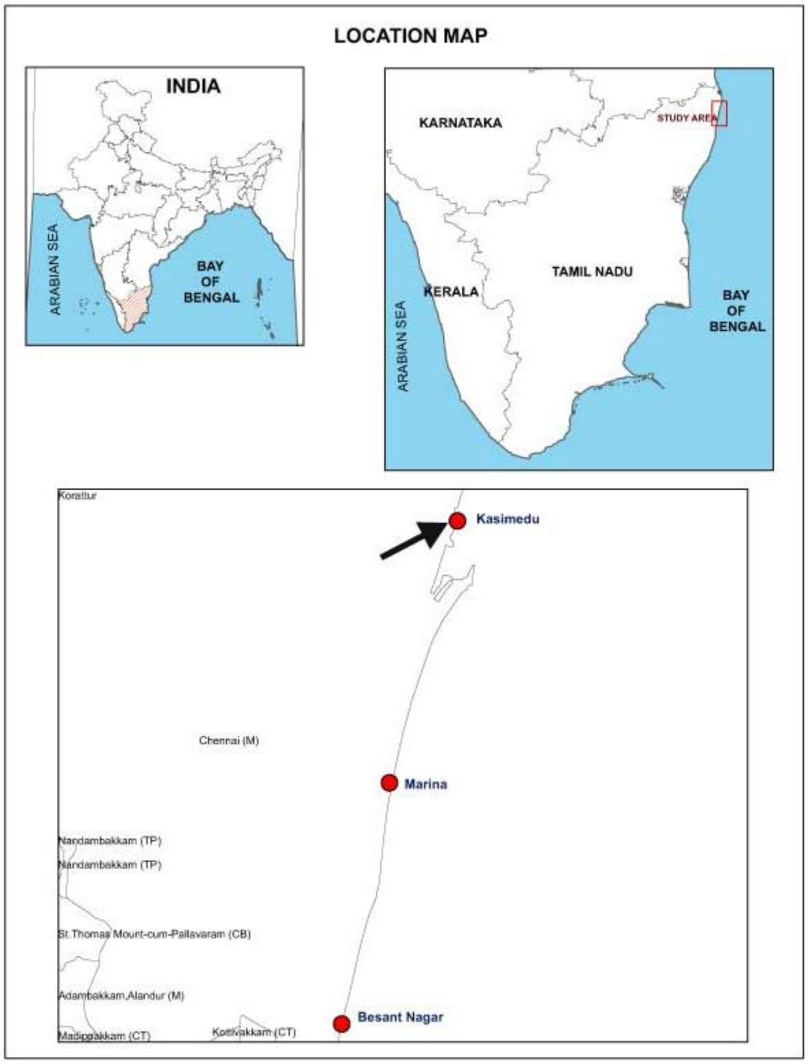

Figure 1. Map showing the collection site: Kasimedu Fishing harbour, Chennai, India.

Xyrichthys.

5. The space between the second and third dorsal spines, in these two species are equal.

The taxonomic history is complicated for many Labrids, as juveniles, male and female can have different colour patterns and morphology, and some early descriptions were limited. In earlier studies, *Xyrichtys bimaculatus* have reported from Chennai coastal waters (CMFRI, 2009) based on these descriptions that *X. bimaculatus* were reported from Mangalore waters (Saravanan et al., 2011). Similarly, *Iniistius bimaculatus* and its distribution and description were done by Veena et al. (2012) from Vishapatnam waters.

Some taxonomic misunderstanding exists between the species of *Xyrichtys* and *Iniistius* previously. The genus *Iniistius* has been considered a synonym of *Xyrichtys* but it is now accepted as a separate genus, different from *Xyrichtys* (Randall and Earle, 2002; Randall et al., 2002).

The observation made by CMFRI (2009) in Chennai coast was hardly a report of *X. bimaculatus*. The taxonomical information are not provided in details. Hence, the present study was the first conformational record of two spot razor fish, *I. bimaculatus* from the Chennai coastal waters, Southeast coast of India.

MATERIALS AND METHODS

On 12 September 2013, two specimens were collected from trawl catches at Kasimedu fishing harbour, Chennai coast (Figure 1). The specimens were brought to the laboratory for taxonomic study following Hubs and Lagler (1947), all morphometrics were measured to the nearest 0.1 mm using Vernier calipers. The samples was preserved in 10% formalin and kept in the Department of Zoology, Sir Theagaraya College, Chennai, India, for further

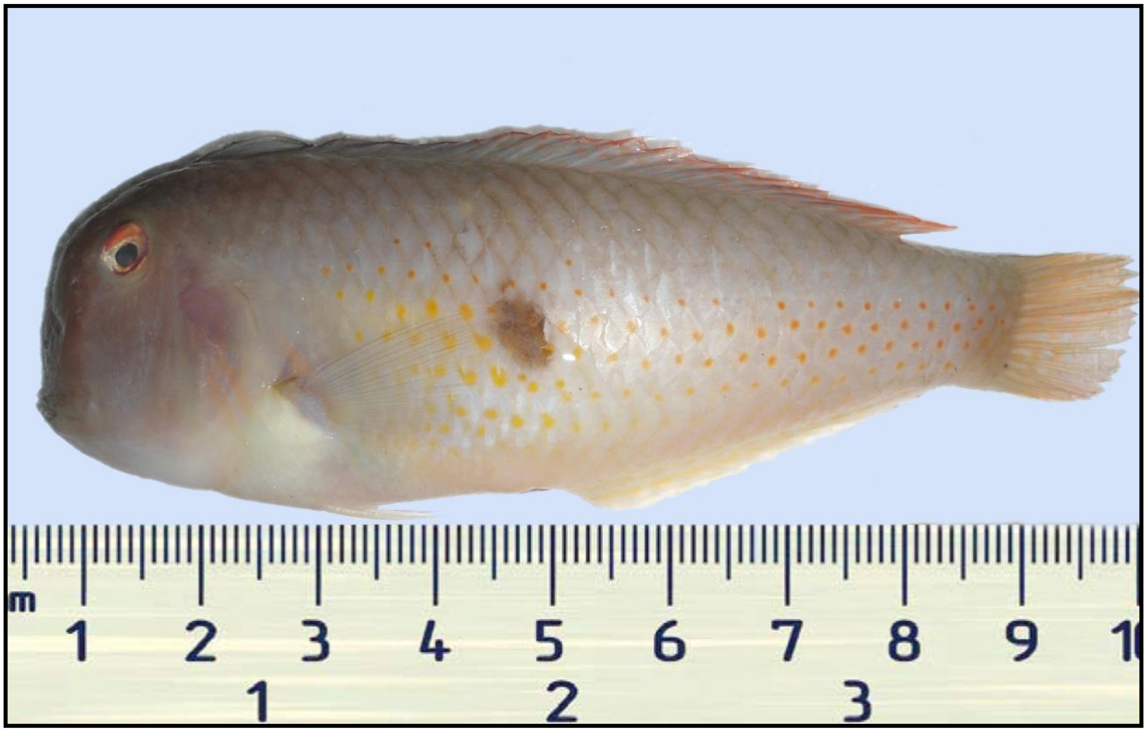

Figure 2. Female *Iniistius bimaculatus* (Ruppell, 1829).

identification processing (Table 1).

Systematics

Class: Actinopterygii
Order: Perciformes
Sub order: Labroidei
Family: Labridae
Genus: *Iniistius*

Iniistius bimaculatus (Rupell, 1829)

RESULTS

Description

Body is deep and very compressed. Dorsal profile of head is strongly lower in the front of eye, snout is very steep and the anterior edge is thin. There is a pair of slender, long incurved, and slightly out flaring canine teeth anteriorly in each jaw. Dorsal profile of snout is nearly vertical, last pored scales on caudal fin base is more pointed than previous pored scales, largest scales are on the side of chest, about half height of largest scales on side of body. Origin of dorsal fin is posterior to vertical at hind edge of eye, first 3 dorsal spines flexible 2-3 times longer than the third spine, membrane between the second and third spines notched is half the length of the third spine, scales are cycloid, very thin and membranous lateral line scales with a single horizontal tubule ending in a posterior pore; Caudal fin is small and asymmetrically rounded (Figures 2 and 3).

Color in fresh condition

Males are pale grey, the scale edges are a little darker, with a blackish spot on mid side below the tip of pectoral fin, spot covers 3 scales in the fifth and sixth rows from top of the body, have a pale yellowish blotch preceding the black spot, a medium blue line at the front of the head, pectoral fin base white, dorsal fin dusky with pale orange thin line along the base of the soft length, bluish line, posterior part of dorsal fin with a series of rows of pale orange spot, anal fin is translucent white with a series of yellowish dashes or elongate spots on fin, mid to upper portion of the caudal fin has a series of narrow vertical, irregular orange stripes. Females lack the black spot on sides.

DISCUSSION

The specimen represents the first record of *I. bimaculatus* from the Chennai coast. However, species of similar appearances may be confused.

It is possible that the specimens collected by Randall and Earle (2002) were described as genus *Iniistius*. In

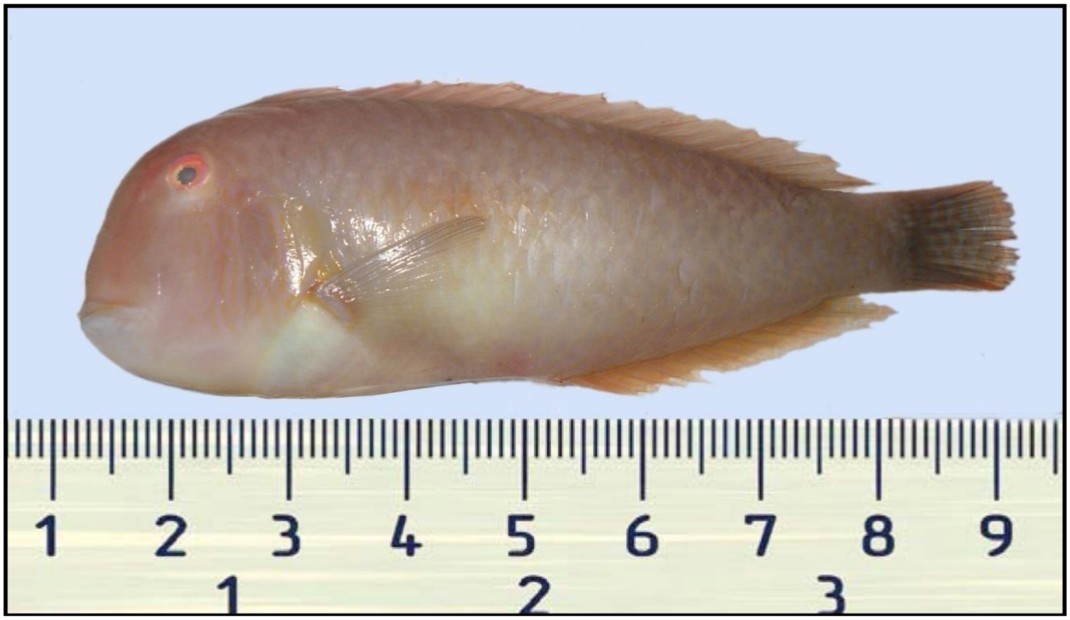

Figure 3. Male *Iniistius bimaculatus* (Ruppell, 1829).

Table 1. Morphometric and meristic characters of *Iniistius bimaculatus* from Chennai coast, Tamil Nadu.

Morphometric characters	Present study female specimen (in mm)	Present study male specimen (in mm)
Total length	141	169
Standard length	128	148
Head length	34	43
Pre orbital length	12	14
Post orbital length	15	17
Eye diameter	7	7
Dorsal fin base	91	109
Pre dorsal length	32	38
Pectoral fin base	11	11
Pectoral fin length	25	29
Pelvic fin base	4	5
Pelvic fin length	17	34
Anal fin length	51	52
Caudal peduncle length	11	21
Caudal peduncle depth	21	23
Caudal fin length	19	21
Body depth	42	56
Lateral lines	19	19
Meristic counts (n)		
Dorsal fin count	IX+12	IX+12
Anal fin count	II + 12	III+13
Pectoral fin count	I+11	I+11
Pelvic fin count	I+5	I+5
Caudal fin count	12	12
Lateral lines	19	20
Weight (g)	46.2	69.6

order to avoid misidentification, typical morphometric and meristic features of *I. bimaculatus* are necessary for confirmation. Palatine bone separate and two neural spines are present, the space between second and third dorsal spines are equal than that of *X. bimaculatus*. Moreover, *X. bimaculatus* can be distinguished from *I. bimaculatus* by the presence of the first two often separated from the rest of the fin by deep notch in the fin membrane or completely detached. In the light of the above, it is concluded that this forms the first report of *I. bimaculatus* from the Chennai coastal waters.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Investigating changes in fish biodiversity in coastal villages of Zanzibar Island, Tanzania

John Sebit Benansio[1]* and Narriman Jiddawi[2]

[1]National Ministry of Livestock and Fisheries Industry, Veterinary Street, Gudele, P. O. Box 123, Juba, South Sudan.
[2]Institute of Marine Science (IMS) Mizingani Road, P. O. Box 668, Zanzibar, Tanzania.

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This study was conducted at the coastal villages of Zanzibar Island to investigate changes in fish biodiversity. The methodology mostly involved face-to-face interviews and structured questionnaires. Findings of this research paper revealed that there are twenty seven families of fish species of economically importance in the study area of which Scombridae is the most dominate species. This research study shows that there is no significant difference on the distribution of fish biodiversity in the coastal villages of Kizimkazki vs. Matemwe p>0.86; Matemwe vs. Nungwi p>0.09 and Nungwi vs Kizimkasi p>0.06. Findings of the research study revealed that out of twenty seven families of fish species of economic importance to the household's income of the fishermen; ten families of those fish species were reported by the highly experienced fishermen to have been depleted over the last four decades. The most devastated fish species perceived by the senior fishermen includes Green hump head parrot fish, Javelin grunter, Rosy dwaft monocle bream, Twinspot red snapper, Green job fish and bicolour. T-test revealed that there is a significant difference on the perception of the fishermen on the changed in fish biodiversity between the three generation. Significant result were found between younger age vs middle age p<0.002; high significant results were found between middle age vs old age p<0.002 and high significant were found between old age vs younger age p<0.000. Findings of the research study revealed that the highly experienced fishermen perceived that the main reasons for the decline of fish biodiversity in the coastal villages of Zanzibar Island were (a) increasing number of fishermen, (b) the uses of destructive fishing gear has devastated marine ecosystem, (c) increasing development of tourism industry have created a new demand for fish market, (d) climate variability and seasonality has contributed negatively on the decline of fish biodiversity. The research study concluded that further decline on fish biodiversity are likely to increase in future unless appropriate enforcement of laws and regulation are established.

Key words: Biodiversity, marine fisheries, perception of fishermen changed, fish species.

INTRODUCTION

Human dependence on marine ecosystem is significant, both in terms of the nutritional value provided by fish and other seafood to the population and in terms of the level of economic security the fishing industry provides for the

*Corresponding author. E-mail: sebitbenansio@yahoo.co.uk.

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coastal communities (Warui, 2014). Despite the importance of fishery resources to national food security and economy, there is evidence that the marine artisanal fishery is economically declining and faces the threat of stock collapse with negative community and economic implications (MLFD, 2012). The impact of this term artisanal fishery is not sufficiently assessed, and the environmental and economic implications of the fishing pressure are unclear (Gotesson, 2012). The change that occurs at marine ecosystem are aggravated by natural processes, making marine ecosystems more vulnerable to changes that previously could be absorbed. The recent documentary film under the titled 'End of the line1' (www.endoftheline.com) describes the uses of highly destructive fishing gears causing severe stock decline attempted to pointed that in future oceans may be left without fish. FAO (2012) report claimed that 57.4% of global fish stocks are fully exploited, of global fisheries 29.9% are overexploited and only 12.7% are underexploited and have the potential to sustain an increase in harvest. Tanzania is not an exception in this realm, trends in the landings of marine resources as evidenced by declining yields of fish and deteriorating conditions of coral reefs suggest that it may be approaching its maximum harvest potential (van der Elst et al., 2005). Fish community appears highly degraded, a situation made worse because the overall size is generally too small indicating high capture of immature fishes. The artisanal fishery along the coastal villages of Zanzibar Island is under high pressure from use of destructive fishing gears and this has contributed directly to the deterioration of coral reefs conditions in most part of Zanzibar Island (McClanahan et al., 2002; Jiddawi and Yahya 2003). To address long term sustainable fisheries management in the small island like Zanzibar, there is a need for the changes of a new regime policy that addresses issues related to environmental degradation, fisheries utilization. The institutional challenge becomes more common in most of the tropical countries as there is a fragmentation of decision making and management. Poor enforcement of laws and regulations have contributed greatly to the failure governmental institutions (De la Torre-Castro, 2006). There is no reliable information or research study that has been conducted in the past or at present to understand the extent on the changes in fish biodiversity in the coastal villages of Zanzibar Island. This research was designed to understand: (1) what are the economic importance fish species in the Coast of Zanzibar Island? (2) Do the fishermen perceive that there is change on the economic importance fish species? (3) How do the fishermen measure the changes on the fish biodiversity?

MATERIALS AND METHODS

The study was conducted in the three coastal villages of Zanzibar Island namely: Kizimkazi, Matemwe and Nungwi, the reasons for the selected the three areas because of their suitability for touristic related activities.

Interviews

Participatory techniques were mainly used to collect qualitative data. Key informal interview were held with the senior government official at department of fisheries in Zanzibar. Face-to-face interview were mainly held with the three difference ages of fishermen namely: younger age fishermen (18 -29 years old, n=53), middle age fishermen (30-49 years old, n=79) and old age fishermen (50-80 years old, n=42). The questionnaire designed for the research study included both open-ended and closed ended questions aims to gain information on the extent to which the three generation of fishermen in the coastal village villages of Zanzibar Island perceived change in fish biodiversity. The fishermen were asked open questions to list all economically importance fish species that are native and familiar to them in the area and how the fishermen' do they perceived changes in fish biodiversity over the past 20 years since advent of tourism development along the coast of Zanzibar Island. The fishermen' were asked to compare quantity of fish they used to catch nowadays in contrast to the fish catches the fishermen used to catch over the past 20 years. In addition, respondents were asked to explain the reason for the decline of fish biodiversity in the area; and the experiences of fishermen were taken into consideration. A total of 170 fishermen households were interviewed from the period October 2011 – February 2012.

Data processing and analysis

Analysis of the data involved triangulation of the information from the field noted, transcribed interviews. Data were coded according to the themes and analysed using statistical packages for social science (SPSS) version (16.0).

RESULTS

Economic importance of fish species along the coast of Zanzibar Island

Findings of the research study revealed that there are twenty-seven (27) families of fish species of economic importance for the household's income of the fishermen, livelihoods and food security in the study area. The research study asserted that Nungwi is the richest fishing village in Zanzibar Island in terms of all families of fish species. For instance, the family Scombridae; (which comprises of Kibua 36%, Sehewa 46%, Nguru Kanadi 26%, Jodari 86%) represent the highest percentages, and followed by the family of Istiophoridae, (Mbasi 78%, Istiophoridae, Nduaro 74%); then followed by family Rhinobatidae 56%; and family Sphyniade 44%; Aterinidae, 38%; Coryphinidae 32%). Table 1 shows the percentage presentation of list of fish species of economic importance to the fishermen. Furthermore, findings of the research study revealed that Kizimikazi is the second richest village among the study sites (Figure 1) in terms of families of fish species. However, Matemwe is the richest village in terms of reef fishery and mollusk. For instance the families of Lethrinidae and 64.41%; Octopodidae 64.41% representing the highest percentages; then followed by Scaridae 40.68%,

Table 1. Shows the percentage presentation of list of fish species of economic importance to the fishermen households 'income (Multiple answers were possible).

Family Name	Local Name	*Kizimkazi % (n=61)*	*Matemwe % (n=59)*	*Nungwi % (n=50)*
Acanthuridae	Kangaja	3.28	18.64	0
Carangidae	Kolekole	31.15	18.64	30
Chanidae	Mwatiko	1.64	0	2
Coryphanidae	Dorodo/Panje	22.25	11.86	32
Gymnuridae	Tenga	14.75	1.69	8
Haemulidae	Karamamba	3.28	0	0
Haemulidae	Kui	4.92	1.69	0
Istiophoridae	Mbasi	42.62	22.03	78
Istiophoridae	Nduwaro	18.03	3.28	74
Lethrinidae	Changu	32.78	64.41	18.03
Lobridae	Gumbasi	18.03	0	0
Loliginidae	Ngasi	34.43	27.12	36
Lutjanidae	Janja	1.69	3.28	2
Lutjanidae	Futundu	3.28	1.69	2
Lutjanidae	Mrongo	1.64	5.08	2
Lutjanidae	Molelis	0	3.39	2
Lutjanidae	Kungu	1.64	3.39	6
Mobulidae	Pungu	13.12	5.08	22
Mugilidae	Mkizi	6.56	11.86	18
Mullidae	Goat fish	13.11	28.81	4
Nemipteridae	Koana	4.92	15.25	4
Nephropidae	Kamba	37.71	20.34	34
Octopodidae	Pweza	34.43	64.41	34
Rachycentridae	Songoro	8.19	5.08	16
Rhinobatidae	Papa fuwanda	31.15	6.78	56
Siganidae	Tasi	59.01	57.63	28
Serranidae	Chewa	6.56	35.59	6
Scaridae	Chore	3.28	0	2
Scaridae	Kangaguruwe	0	6.77	2
Scaridae	Pono	18.03	40.68	30
Scombridae	Kibua	14.75	28.81	36
Scombridae	Sehewa	16.39	3.28	46
Scombridae	Nguru (Kanadi)	11.47	3.28	26
Scombridae	Nguru	70.49	15.25	42
Scombridae	Zanuba	0	11.86	22
Scombridae	Jodari	44.26	11.86	86
Rna lewini	Papa pingusi	22.95	11.86	44
Sardinella	Dagaa	27.87	15.25	38
Sphyraenidae	Mzia	26.33	38.98	38
Xiphidae	Nduaro	13.11	1.69	26

Sphyraenidae 38.98%; Serranidae 35.59%; Mullidae 28.81%, and Acanthuridae, 18.64%. In conducting statistical test on the distribution of fish biodiversity in the coastal villages of Zanzibar Island. T-test analysis shows that there is significant difference in fish biodiversity between the Kizimkazi vs Matamwe t-value =0.594, df=80, p=0.553 and p>0.86; Matemwe vs Nungwi t-value=-1.776, df=80, p=0.079 and p>0.09; while Nungwi vs Kizimkazi t-value=-1.283, df=80,p=0.202 and p>0.006.

Perceptions of fishermen on changed in fish biodiversity in Zanzibar Island

Findings of the research study indicated that the majority

Figure 1. Study area.

(80%) of the interviewed fishermen perceived that they have witnessed a changes in fish biodiversity along the coastal villages of Zanzibar Island. For instance out of the twenty seven families of fish species of economic importance to the households 'income of fishermen in Zanzibar Island, 10 families of fish species were reported by the fishermen' to have been depleted over the four decades. Discussion with the highly experienced fishermen perceived that the most devastated fish species of economic importance such as Chanidae (Milk fish), Haemulidae (*Javelin grunter*, *Saddle fish*), Nemipteridae (Rosy *dwaft monocle bream*), Rhinobatidae (*Giant guitarfish*) and Scaridae (*Green humphead parrot fish, bicolour fish*). However, the families of fish species such as Lobridae (*Humphead wrasse*), Lutjanidae (*Emperor snapper*, *Green job fish*, *Twinspot red snapper*, *and Ruby snapper*), Mobulidae (*Montar ray*), Serranidae (groupers in general), and Sphymidae (*Scallop hammerhead*) were reported by the three generation of fishermen to have been declining nowadys see Table 2 below. The perceptions of fishermen' from the three generation in the coastal villages vary considerable, the mean average of fish species claimed by the young aged fishers to have have been declined nowadays 1.57±2.18

Table 2. Fish biodiversity cited by the three generations of fishermen' to have been declining over the past 20 years based on the traditional knowledge and experience of fishermen.

Family Name	Local Name	Young % (n=50)	Middle % (n=78)	Old % (n=32)
Carangidae	Kolekole	4	3.85	12.5
Chanidae	Mwatiko	0	21.79	56.25
Coryphanidae	Panje	0	2.56	0
Gymnuridae	Tenga	4	2.56	9.37
Haemulidae	Kui	0	1.28	25
Haemulidae	Karamamba	0	0	15.63
Istiophoridae	Nduwaro	4	5.13	6.25
Istiophoridae	Mbasi	6	2.56	0
Lobridae	Gumbasi	0	3.85	15.63
Lutjanidae	Molelis	0	2.56	3.13
Lutjanidae	Fatundu	0	5.13	50
Lutjanidae	Mrongo	0	2.56	9.37
Lutjanidae	Kungu	0	2.56	25
Lutjanidae	Changu	4	1.28	3.13
Mobulidae	Pungu	0	2.56	6.25
Nemipteridae	Sorobika	0	0	18.75
Nemiperidae	Sasare	6	3.85	18.75
Rachycentridae	Songoro	6	5.13	3.13
Rhinobatidae	Papa fuwanda	2	38.46	81.25
Serranidae	Chewa	2	5.13	6.25
Scaridae	Kangaguruwe	0	14.10	37.5
Scaridae	Chore	0	1.28	18.75
Scombridae	Nguru (Kanadi)	20	12.82	9.37
Scombridae	Kibua	6	1.28	0
Scombridae	Sehewa	2	2.56	0
Sphymidae	Papa Pingusi	10	28.21	50
Xiphidae	Nduwaro	6	2.56	6.25

(Mean±SD) in contrast to the average mean of fish species cited by the middle aged fishers 'was 4.89±7.08 (Mean±SD) and the average mean for the old aged fishers was 5.57±6.48 (Mean±SD).

Statistical analysis of T-Test shows that there is a significant difference between the younger age fishermen verse middle age fishermen where t-value =-1.642, df=54, p=0.106 and p<0.002. Furthermore, the statistical analysis of T-Test shows that there is a high significant difference between the middle age fishermen and old age fishermen where t-value =-2.654, df=54, p=0.010 and p<0.008. In conducting T-Test analysis between the old age fishermen and the younger age fishermen indicates that there is a highly significant difference between these generation, t-value =-3.642, df=54, p=0.006 and p<0.000.

Perceptions of fishermen on the current fish catch in the coastal villages

Findings of research study revealed that that the majority of fishermen (80%) in the coastal villages of Kizimkazi (80%); (50%) in Matemwe and (90%) in the coastal village of Nungwi respectively stated that there was a serious decline of fish stock. However, (24.59%) of fishermen in the coastal village of Kizimkazi perceived there is more fish stock in the area. Secondary data collected from the Department of Fisheries on fish catches in metric tons (MT) and the number of fishermen along the coastal villages of Zanzibar from 1990 – 2011 show trends of fish catches in Zanzibar supported by the government statistician in the Department of Fisheries (Figure 2).

Beginning from period between 2003 – 2011 the Department of Fisheries in Zanzibar had witnessed serious increased by 50% of local communities in the coastal villages got recruited in the fishing business (Department of Fisheries, 2010).

Experiences of the fishermen in the coastal village of Zanzibar Island

The interviewed fishermen in the research study areas

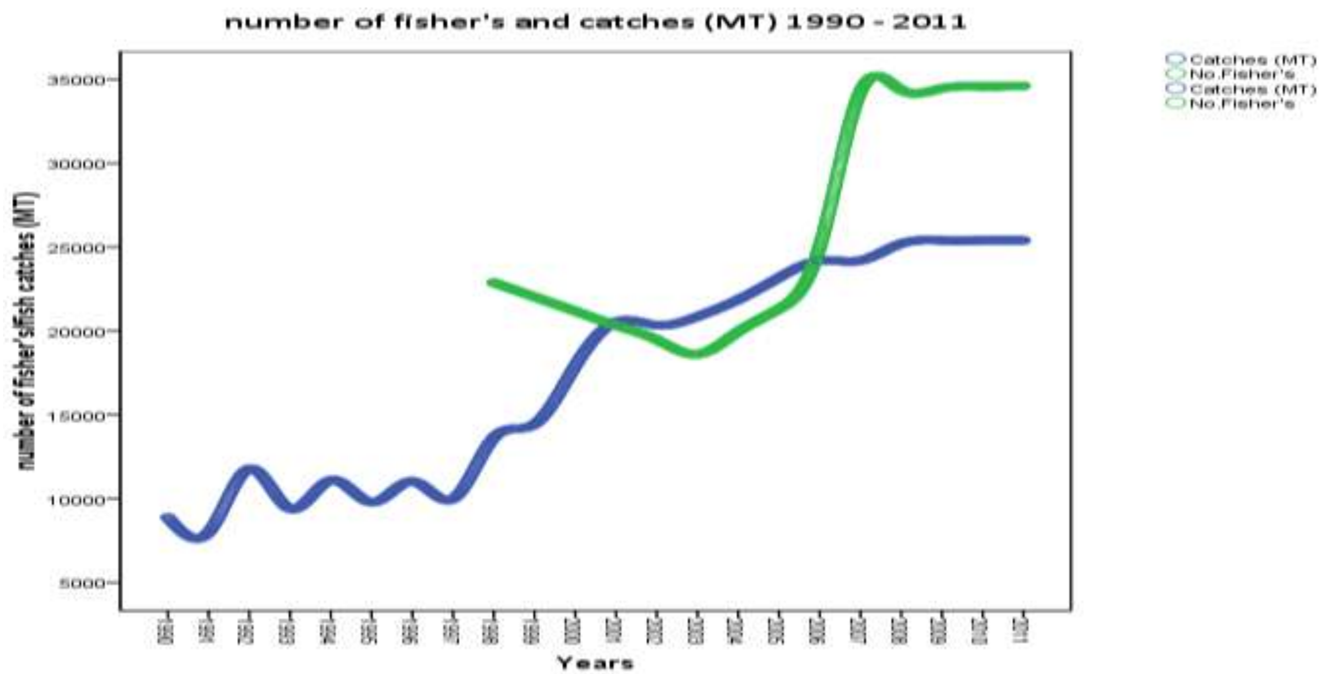

Figure 2. Fish catches (MT) and the number of local fisher's in Zanzibar Island. Source: Zanzibar Fisheries Department.

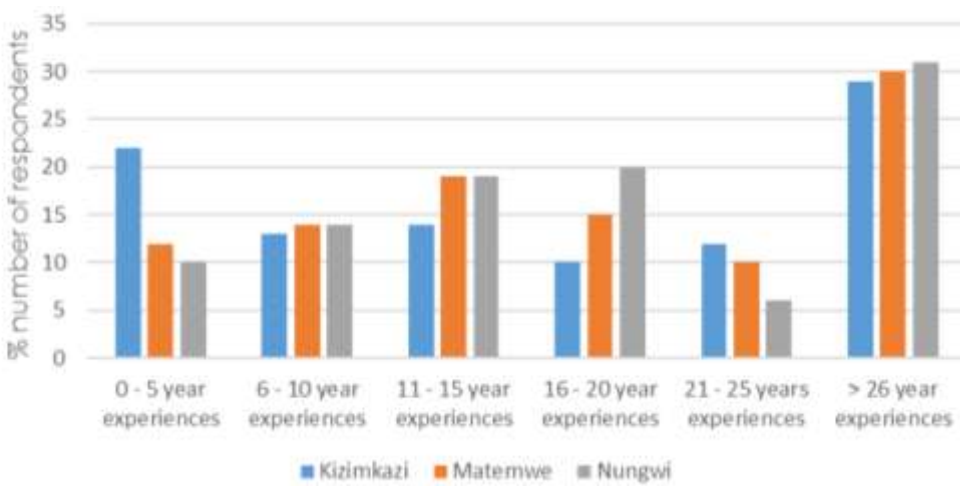

Figure 3. Shows the experience of the fishermen in research area of study.

revealed that the majority (31%) in the coastal village of Kizimkazi, (30%) in Matemwe and (29%) in Nungwi were highly experienced fishermen with more than 26 years old actively engaged in fishing activity along the coastal villages of Zanzibar Island. However, the experience of middle age fishermen ranging from 16 – 20 years old fully participating in fisheries related activity represent (10%) in Kizimkazi, (15%) in Matemwe and (20%) in the coastal village of Nungwi. Then followed by the fishermen with experience ranging from 11 – 15 year experiences 14, 14 and 19% respectively in the coastal village of Kizimkazi, Matemwe and Nungwi presented in Figure 3.

DISCUSSION

Economic importance fish species in the coast of Zanzibar Island

The marine ecosystem of Zanzibar Island is very rich in fish biodiversity. It is interesting that fish biodiversity varies from one coastal village to another based on the traditional knowledge of the fishermen in the research area of study. For instance it was observed that Scombridae is the most dominate fish species along the coastal villages Zanzibar Island during the season of south east trade wind. Although the coastal villages of Zanzibar Island shared the environment, the abundance of fish biodiversity varies from one coastal village to another. The lead author noted that *Nugwi and Kizimakzi* were the richest fishing villages with the majority of large predatory fish species. However, the coastal village of Matemwe is dominated by the coral reef fisheries. Key informant interview with the senior official at the department of fisheries in Zanzibar revealed that there is 19 families of fish species of economic importance which are used in collection of government fish statistics within the Zanzibar Department of Fisheries. The new recorded families of economic importance species of fish that were not found in the record of the Department of Fisheries were Haemulidae (*Javelin Griunter and Saddle fish*), Lobridae (*Humphead Wrasse*), Nemipteridae (*Rosy dwaft monocle breams*), Scaridae (*Bicolour parrot fish and Green humphead parrot fish*).

Perceptions of fishermen on change in fish biodiversity in Zanzibar Island

The senior experienced fishermen in the research area of study perceived that changed in fish biodiversity along the coastal villages of Zanzibar Island have been categories into four different reasons. (a) the fishermen perceived that coastal population growth, has increased the number of fishermen along the coastal villages (b) the uses of destructive fishing gears has devastated marine ecosystem (c) increasing development of tourism industry along the coastal villages of Zanzibar Island has created a new demand for fish market (d) climate variability and seasonality has contributed negatively for the decline of fish biodiversity. The highly experienced fishermen perceived that families of fish species such species such as Lutjanidae (*Emperor snapper*), Rhinobatidae (*Giant guitarfish*), Scaridae (*Green humphead parrot fish*), Scombridae (*Kanadi-kingfish*) and Sphyranidae (*Scallop hammerhead*) are the most threatened fish species in the study area. For instance the fishermen that fish species such as *Green humphead parrot fish, Javelin grunter, Twinspot red snapper, Rosy dwaft monocle bream, and Green job fish* started to disappeared systemically over the last four decades. The observed results are in line with the study conducted by Katikiro (2014); Division of Fisheries (2013) and van der Elst et al. (2005) whom lamented that decline of fish stock in the western Indian ocean of Tanzania was considered back to 1960s, but it is likely some depletion might have occurred prior to this since even low-level artisanal fishing from ancient times. Robert (2003) concluded that the fishing communities at the coastal villages of Zanzibar Island stated that the fish catch rate of demersal fish species and other fishery resources such as octopus, squid, snail (for shell), sea cucumber and other intertidal organisms are declining. It is interesting that most of the fish species mentioned by the highly experienced fishermen to have been depleted are native and familiar to the fishermen in the respective fishing villages in Zanzibar Island. The lead author noted that the name of fish species mentioned by the highly experienced fishermen in the coastal villages were not found in the record of the Department of Fisheries in Zanzibar. Realistic information pertaining to fish catches was difficult to be obtained due to the daily and seasonal variability. The fish species and biodiversity found in the recorded data of the Ministry of Livestock and Fisheries, Department of Fisheries in Zanzibar Island were categorized into a group. However, the fishermen in the coastal villages reported the individual fish species. For instance the lead author observed capture of groupers only twice during the period of data collection in the research areas of study. Informal discussion with the highly experienced fishermen revealed that groupers were the most common species and at the same time many Zanzibar is preferred to consume this species. The highly experienced fishermen described that although groupers can be caught on seasonal basis, it is very difficult to capture groupers nowadays. The lead author was not familiar with the species, generic information on ‘groupers’ was sought, followed by a discussion of which fish species in particular is becoming rarer. There is no reliable or sufficient data on these resources that can really support such perception despite their importance to fishermen. Katikiro (2009) stated that fishermen reported fish species of less commercial importance have decline without the knowledge of fishermen.

Perceptions of fishermen on the current fish catch in the coastal villages

The perceptions of fishermen in the research area on the current fish catches in the coastal villages of Zanzibar Island varies considerably from one fishermen to another. For instance the majority of younger fishermen in the coastal villages of Kizimkazi perceived that there is abundance of fish catches in area due to the fact that Menai Bay is Marine Protected Area where fishermen are restricted to open season and closed fishing seasons. The lead author noted that the majority of the younger-star generation in the coastal village of Kizimkazi were actively involved in ecotourism related income generating activities such as dolphin tour, game fishing, tour guides, and taxi driver which supported the household’s income of the younger fishermen. However, the fishermen in the coastal villages of Matemwe and Nungwi expressed that there is a rapid increase in the number of the coastal communities venturing into fisheries related activities nowadays, this has contributed negatively on the decline of fish biodiversity in the area. The senior fishermen perceived that the increasing number of the younger fisher's in the coastal villages as a results of rapids development of tourism industry that have created a new demand of fish market in the coastal villages. The observed results are in line with the study conducted by Jiddawi and Öhman (2002) who revealed that the advent of tourism development in the 1990s along the coastal villages of Zanzibar Island have motivated fishermen to concentrate highly on demersal fish species such as snappers, groupers, emperors, parrotfish and this has greatly contributed to the decline of catch per unit effort as well as reduction in fish sizes. Department of Fisheries (2010) describe that the number of fishermen has increased by 50% from 2003 – 2011, the increased in the number of coastal communities into fishing activity may lead to further degradation of marine fisheries resources along the coastal villages of Zanzibar Island. The lead author noted that sometimes the fishermen were returning back from their respective fishing ground without a single fish in their fishing craft/boats.

Experiences of the fishermen in the coastal village of Zanzibar Island

The experiences of fishermen is considered as important because it allowed social scientist to understand specific information of the area based on the traditional knowledge and experience of local community within that specified geographical location. It is interesting that there was a gradual difference at the level of experience among the fishermen in the coastal villages of Zanzibar Island. For the instance the highly experience fishermen with more than 26 years of experience in the coastal villages of Zanzibar Island represent the smallest percentage in the fishing communities in contrast to experienced middle aged fishermen. The experience of local communities is an advantage of connected the researchers with the nature and what happened over the last decades. Lotze et al. (2006) describes that enhanced the past knowledge of the local communities are needed to support our recent data in conducting research. For instance if scientists will devoid past experience then evidences such as extirpation of large vertebrates around the Mediterranean which are said to extend far beyond Christian will be vague. Sáenz-Arroyo and Roberts (2008) revealed that people always view the environment simply by inclining to how they found it.

Conclusion

The serious decline on the economic important fish species and biodiversity was attributed to factors such as increases in the number of fishermen, the uses of destructive fishing gears has devastated marine fisheries resources, increasing development of tourism industry has created a new demand for fish market and climate variability and seasonality has contributed negatively on the decline of fish species and biodiversity. The highly experienced fishermen perceived that changed in the abundance of fish biodiversity returned back in 1960-1970s is the period where they started to observe dramatic changed in certain type of fish species. Secondary data collection from the ministry of livestock and fisheries, department of fisheries described that there is a systematic increases by 50% in the number of new recruits fishermen from 2003 – 2011 which shows the real threat to marine resources, not only fisheries only. The advent of tourism industry along the coastal villages of Zanzibar Island has created a new demand of fish market which is an incentive for the fishermen. To date fishermen in the coastal villages of Zanzibar Island were targeting high value fish such as King fish, Yellowfin tuna, skipjack tuna, kawakawa, snappers and groupers, sail fish, octopus, lobsters and squid because of it high demands in the tourist resorts and hotel. The research study concluded that further decline on fish biodiversity are likely to increase in future unless appropriate regulation and enforcement of laws and regulation are established.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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Full Length Research Paper

Movement patterns of Chilean flounder (*Paralichthys adspersus*) inside Tongoy Bay (central northern Chile): Observations using passive acoustic telemetry

Pablo M. Rojas

División de Investigación en Acuicultura, Instituto de Fomento Pesquero P. O. Box 665, Puerto Montt, Chile.

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The movement patterns of juvenile and adult Chilean flounder (*P. adpersus*) were investigated inside Tongoy Bay using ultrasound signal acoustic receivers from June 2012 to March, 2013. Flounder landings in Tongoy Bay and Puerto Aldea from December 2011 to March 2013 were examined. Multiple regression analysis indicated that the Catch per Unit of Effort of Chilean flounder was significantly and negatively related to temperature and depth. Analyses of site- and time-specific length-frequency distributions indicated movement of Chilean flounder on the time scale of weeks, which was likely due to emigration of fish >30 cm in total length. A mark-recapture study was performed. Visible elastomer paint was used to tag 7,510 Chilean flounder. A total of 12 Chilean flounder individuals of different lengths were tagged with an ultrasound transmission device to monitor their movement inside Tongoy Bay. Adults flounder showed increased activity inside Tongoy Bay during the study period, likely due of the differences in length among the released individuals. Although differences were detected in the area occupied by juvenile and adult flounders in Tongoy Bay, it was also noticed that the smaller sized individuals exhibited changes in behavior after implanting the transmitters that resulted in impaired capacity to move freely.

Key words: Chilean flounder, acoustic telemetry, movement patters, landing, mark-recapture.

INTRODUCTION

Chilean flounder (*Paralichthys adspersus*) is a flatfish with bentho-demersal habits of commercial and recreational importance distributed from the locality of Paita (northern Peru) to the Gulf of Arauco (Chile), including the Juan Fernández Archipelago (Pequeño, 1989; Sielfeld et al., 2003). As in the case of other fish, flounders exhibit remarkable bathymetric movements and horizontal migrations. Seasonal variations, the extent and direction of these movements in flounder stocks can differ considerably between species and geographic areas as a result of the large amount of biotic and abiotic factors (that is, temperature, salinity, dissolved oxygen, depth and type of substrate, currents, availability of food, competition, among others; Able et al., 2005).

In this regard, the habitat use patterns for this species may vary at different spatial, time scales, and ontogeny

E-mail: pablo.rojas@ifop.cl.

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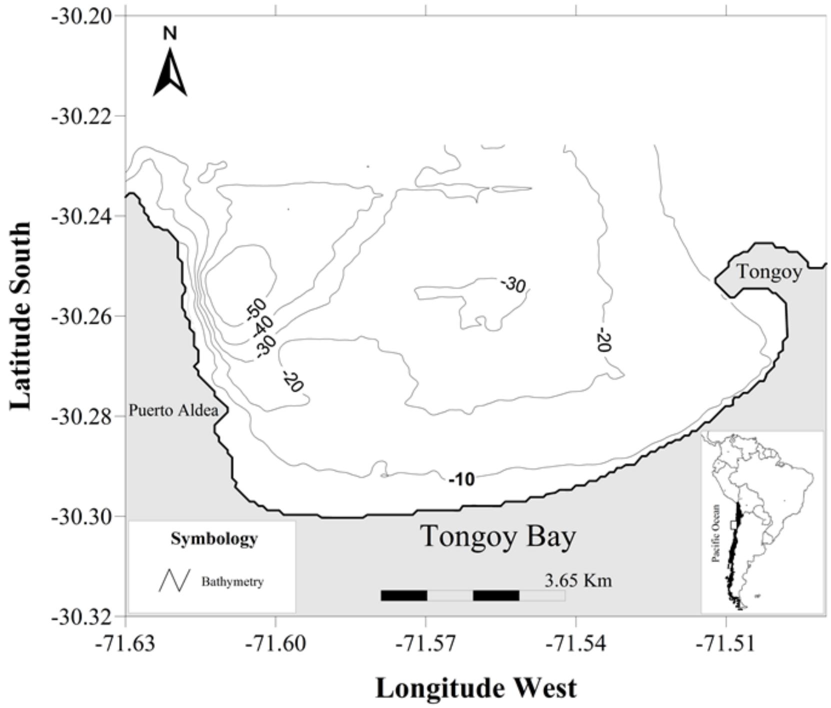

Figure 1. Location of Tongoy Bay, central northern Chile.

(Armstrong, 1997; Howell et al., 1999; Goldberg et al., 2002). The movement of individuals between habitats can affect instantaneous abundance, growth and mortality estimations, and therefore, the quality of the assessment of a specific habitat. The movement of marine fish inside coastal and estuarine systems may occur in response to resource availability (resource-directed dynamics), or as a result of migration processes (non-resource mediated migration; sensu Dingle, 1996). It is essential to study the movement and migration under short spatial and time scales in order to understand the role of coastal and estuarine systems as nursery areas for juvenile marine fish, and assess various habitats (Saucerman and Deegan, 1991; Beck et al., 2001; Burrows et al., 2004).

Seasonal distribution patterns were obtained from catch data analysis and landing records (SERNAPESCA, 2012). Nevertheless, these data sources offer a limited perspective of Chilean flounder residence patterns and habitat use. In addition, these traditional sampling sources to obtain distribution data cannot identify individual movement variability or reproductive behavior.

The magnitude of variability in individual distribution patterns of Chilean flounder is still little known, even when it comes to the most commercially valuable fish species (Able and Grothues, 2007), partially because it is still necessary to recognize the importance of learning about the behavior of a group of fish defined as cohesive fish groups within a stock that display a common movement pattern (Cadrin and Secor, 2009). To this regard, acoustic telemetry offers new opportunities to investigate the movements and individual behavior of fish at the fine scale. In addition, this technology makes it possible to recognize groups within stocks (Secor, 1999) and offer information related to the link between coastal stocks (Able, 2005).

The use of acoustic telemetry has made it possible to obtain high resolution data related to the behavior of juvenile flounder in the Gulf of Maine (Fairchild et al., 2009). Nevertheless, in Chile, the scarce experience about the use of acoustic telemetry has focused on movement patterns of fresh water fish (Piedra et al., 2012). The aim of this study was to research the seasonal distribution and movement of a group of flounder inside Tongoy Bay using passive acoustic telemetry. The movement assessment was done using two complementary strategies: (1) The abundance, distribution and length frequency of the flatfish captured in different fishing zones during an annual period was determined, and simultaneously (2) the dispersion distance of the individuals was estimated by means of a tagging and recapture study.

MATERIALS AND METHODS

Study zone

Tongoy Bay is located in the center-northern zone of Chile (30°12'S - 71°34'O; Figure 1) a region with semi-arid characteristics. The bay is open toward the north and stretches across an area of 55.86 km^2,

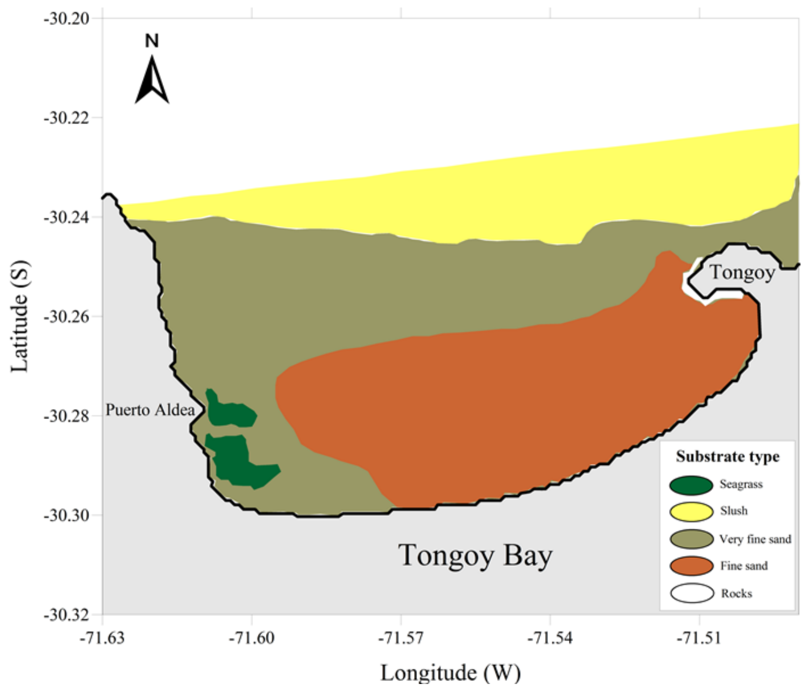

Figure 2. Distribution of surface marine sediments in Tongoy Bay.

with a volume of 2.01 km^3 and the mouth section is 0.2 km^2. The average depth of the bay is 25 m. Large part of the habitat that is available for early stages and adult Chilean flounder is relatively free from vegetation, except for the presence of seagrass (*Heterozostera tasmanica*) in the extreme southern part of the bay. The sediment in Tongoy Bay varies from very fine-to-fine sand. In general, the prevailing substrate is very fine sand (~0.11 mm diameter). Nevertheless, very fine sand largely dominates westward and fine sands eastward (Figure 2).

Flounder movement patterns

The movement of flounder was assessed using three complementary strategies. First, data obtained from landing records in Tongoy Bay were used to generate length frequency distributions for each capture zone in order to infer movement patters with respect to length. The second strategy consisted in an intensive tagging and recaptures strategy to reconstruct the individual movement of fish during the same time period. Finally, ultrasound signal transmitters were implanted in a group of flounder to monitor their movement routes inside the study area.

Spatial and time abundance of flatfish

To assess the habitat use patterns in short time and space scales, Tongoy Bay was divided into 34 zones, each of approximately 4 km^2 (Figure 3). This way, the landing information was recorded on the basis of geographical dimensions. Flounder landings in Tongoy Bay and Puerto Aldea from December 2011 to March 2013 were examined (Tongoy Bay; Figure 1). Yield estimation in terms of Catch per Unit of Effort (CPUE) was used as abundance index expressed in grams per hour. A CPUE for each catch was obtained and this value was used as a unit, in such a manner that the different CPUEs estimated by category (locality, month, depth) were determined as the average CPUEs by catch for each category. Individuals harvested with the use of gill nets (3 m width, 45 m long and 15 to 20 cm mesh size) were measured and weighed *in situ*, and later grouped according to length ranges of 2 cm total length (TL), in order to reduce measurement variability and better highlight the catch length frequency distribution.

Data analysis

A variance analysis was used to assess differences in landings of flounder in terms of time and between fishing zones (ANOVA; Spiegel, 1991). Anderson Darlingand Bartlett test (Stephens, 1974) were used to assess if the data complied with variance normality and homogeneity assumptions. A log transformation was used where appropriate (x+1) before applying ANOVA. Length frequency distributions generated for various landing periods and fishing zones in the bay were analyzed with a Kruskal-Wallis non-parametric test (Gotelli and Ellison, 2004) using the following length classes: 5-20, 21-40, 41-60, 61-80 and >80 cm TL.
Backward stepwise multiple regression analysis (F-to-remove = 1) was used to examine the relationship between the CPUE of Chilean flounder (*P. adpersus*) with temperature, salinity and depth. We checked for collinearity among abiotic variables using correlation analysis, and found none were highly correlated with each other ($r \leq 0.33$). Landing data obtained during the study were pooled into summer, autumn, winter and spring periods. CPUEs were log(x+1) transformed. Abiotic parameters deviated only slightly from normality and, therefore, were not transformed. All statistics analysis was made using the STATISTICA 7.0 statistics package (2005).

Mark-recapture

A total of 7,510 flounder individuals were tagged with elastomeric

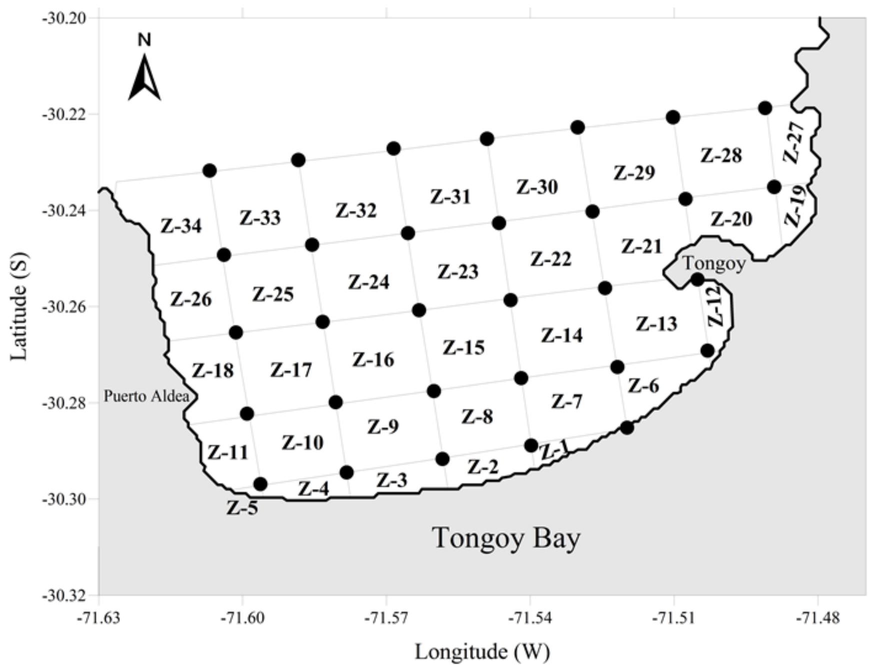

Figure 3. Grids with flounder fishing zones in Tongoy Bay.

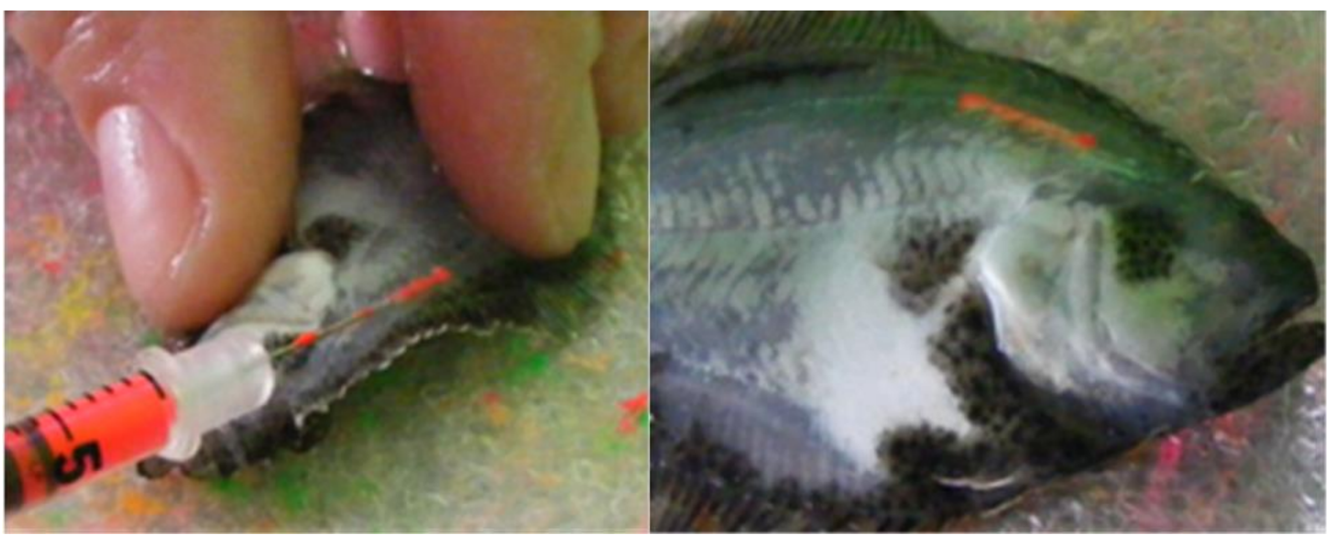

Figure 4. Tagging flounder with elastomeric paint injection.

paint. A visible implant elastomer tagging system was used (Northwest Marine Technologies, Seattle, Washington, USA). The elastomer was applied through injection with a hypodermic needle in liquid form that solidified within 24 h. The tags were implanted in the operculum on the fish's blind side, when the length allowed it, and under the dorsal fin, on the blind side (ventral) in small fish (Figure 4). The flounders were weighed and measured, and then classified in six length classes, assigning different color to each one (Table 1). After tagging the fish, they were placed in observation during 4 days in order to detect negative effects such as abnormal swimming or lack of response to tactile stimulation, and assessed the tag retention rate and if the tagging process caused mortality. The fish were released in May, 2012 off Puerto Aldea Bay, and the recapture efforts were made between June 2012 and January, 2013, with the use of transects placed parallel to the coastline.

The distance between the release zone and transects used in the recapture for each individual was calculated. Maximum and minimum dispersion distances between the central release point and the recapture point were estimated using the initial and final trawl coordinates where each individual was recaptured. Trawling operations (nets 100 m length and 2 m height, with a cod end in the mid sector) were carried out in conditions of relatively low tide (0-75

Table 1. Length classes with assigned color and number of flatfish marked with elastomeric paint.

Color mark	Size range (cm)	Number of marked fishes
Red	5.0 - 6.9	1,363
Pink	7.0 - 8.9	1,304
Orange	9.0 - 10.9	924
Yellow	11.0 - 12.9	1,319
Green	13.0 - 14.9	1,300
Blue	15.0 - 16.9	1,300
Total		7,510

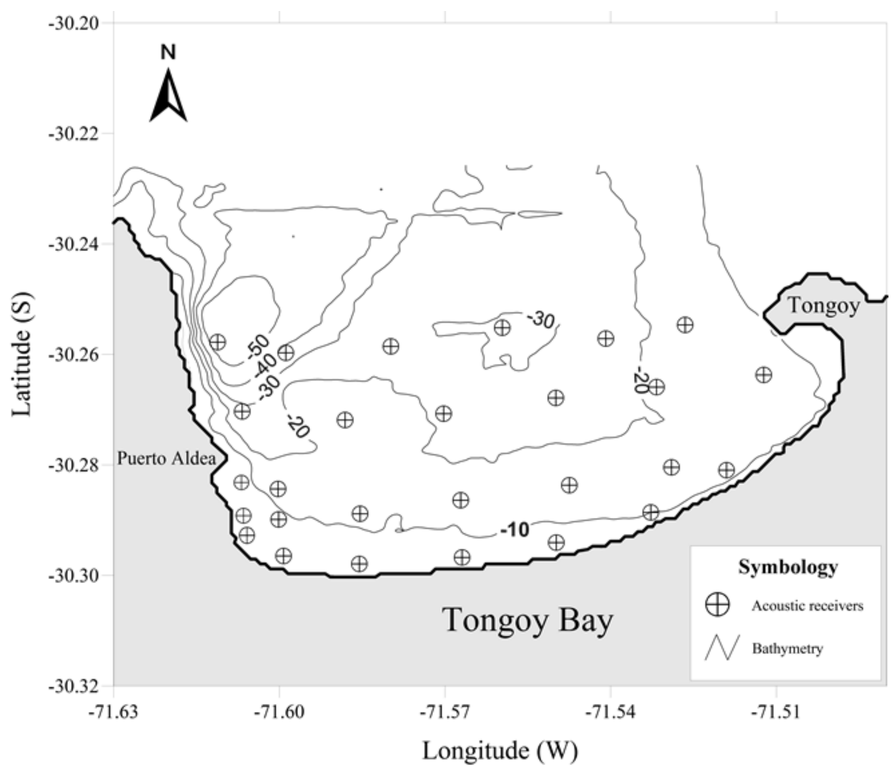

Figure 5. Tracking acoustic receivers (VR2W) anchored in Tongoy Bay.

cm above the mid-level of the lowest tide), therefore, abundance estimations by area unit were made with the low tide areas. In shallow coastal systems, flounder density might vary on the basis of tide level, implying that our stock size estimations probably underestimate the real stock size. To carry out the spatial analysis of the fish recapture information, satellite images of Tongoy Bay were used to create polygons that were representative of the study area. Habitat areas available for flounder and the perimeters of any given area in the bay were calculated with the use of the ArcMap program.

Acoustic telemetry

A total of 9 acoustic ultrasound signal receivers were anchored (Vemco VR2W-69 kHz) during a period of 9 months in order to determine the movement patterns of juvenile and adult Chilean flounder (*Paralichthys adpersus*) inside Tongoy Bay, (June 2012 - March 2013). The equipment's configuration allowed us to cover an area of approximately 42.1 km^2 accounting for 74.4% of the total (55.9 km^2) area of Tongoy Bay (Figure 5). The receivers were anchored in zones with depths up to 50 m, therefore, the anchoring operations area was limited by an isobath of 50 m depth. The position of receivers was shifted regularly to cover the entire study area, in accordance with the manufacturer's technical specifications that indicated a range of 300 to 400 m of signal reception. In addition, acoustic signal precision tests were made in the study area using a hydrophone (VR100).

To monitor the movement of flounder in Tongoy Bay, a total of 12 wild different sized individuals (Table 2) were marked with ultrasound transmission devices (19 mm length; 6 mm diameter) (Vemco V7-2x). Each transmitter has an average pulse frequency

Table 2. Identification of flounders tagged with tracking devices (tag) [Codes assigned to each transmitter are represented by abbreviations ID and SN (receptor code)].

Fish size (cm)	Number fishes	Color	ID	SN
10	1	Pink 1	4451	1130187
18	1	Pink 2	3880	1127425
21	1	Red 1	4457	1130193
23	1	Red 2	4453	1130189
25	1	Yellow 1	4454	1130190
27	1	Yellow 2	4455	1130191
32	1	Green 1	3879	1127424
34	1	Green 2	4452	1130188
39	1	Blue 1	3877	1127422
40	1	Blue 2	4456	1130192
47	1	Orange 1	4450	1130186
49	1	Orange 2	3878	1127423

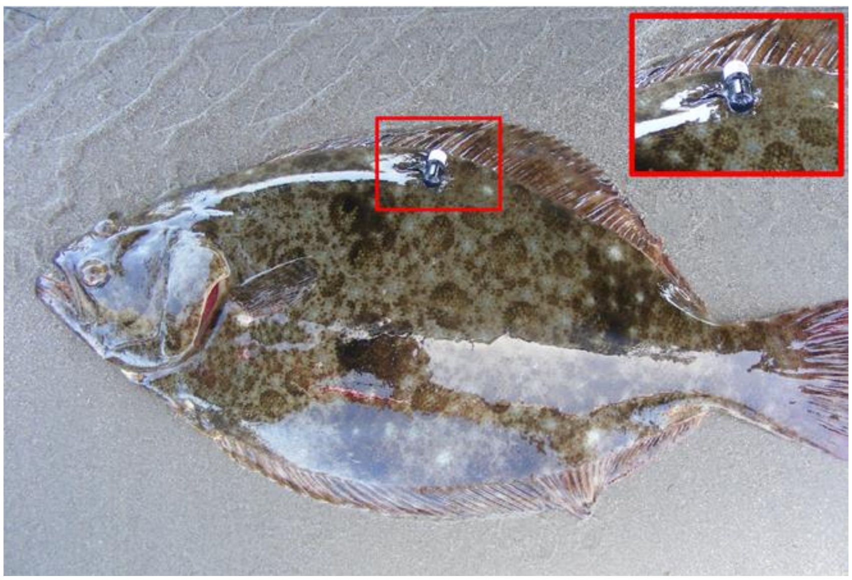

Figure 6. Ultrasonic transmission device (tag) implanted in the dorsal region of a Chilean flounder. The red square indicates the transmitter location.

of 80 s (range = 40 - 120 s) and a battery life of 384 days. Each fish was anesthetized with a benzocaine anesthetic tranquilizer for fish (BZ-20®) in a 1 mL solution: 5L BZ-20 before implanting the tags on the dorsal side of the fish (Figure 6).

After implanting the fish, the affected area was covered with an anti-inflammatory antibiotic for topical application (Terracortril Spray 125 ml) in order to avoid infections associated to the implant. In parallel, the basic data of each fish was recorded (weight and length) and the tag code number. Before being released, the tagged flounder were kept under recovery during a period of seven days to monitor the healing of the wound and the tag retention. The use of ultrasound transmission devices in fish was subject to the following previous considerations:

1. Tag implant tests: without affecting fish behavior while in captivity.
2. Receiver scope test (VR2): 300 - 400 m.
3. Accuracy test with hydrophone (VR100): positioning error of ±4.09 m.

The flounders were released following a visual inspection by divers in order to monitor the response capacity (that is, search for shelter, camouflage, etc.) displayed by each individual in the presence of potential predators.

Distance covered and distribution area

The data stored during the study period (9 months) in acoustic receivers (Vemco VR2W-69 kHz) were downloaded with a VUE 1.4.2 software (VEMCO Ltd.). The information was organized and coded in data bases, indicating if the presence of tagged fish was

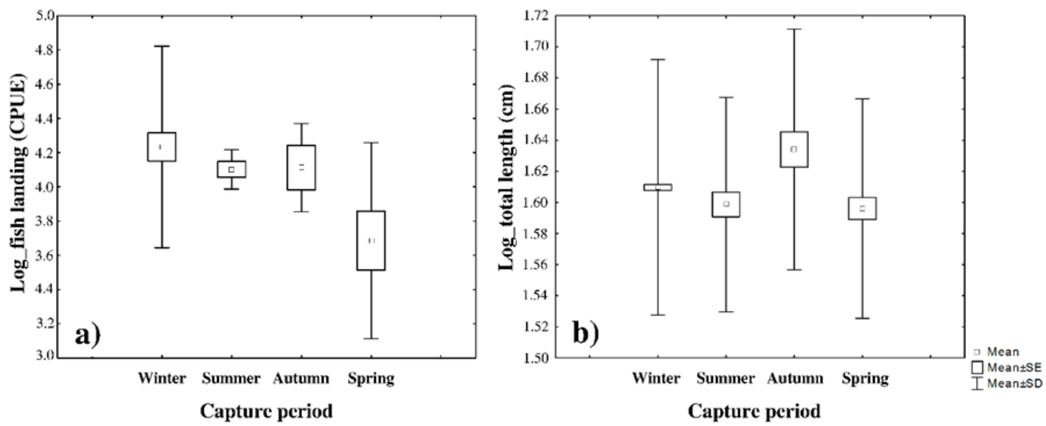

Figure 7. Abundance and length variations of Chilean flounder in Tongoy Bay during the study period, respectively.

detected within a day. The site fidelity was assessed as the probability of detection by one or several receivers with respect to the time elapsed since the release of the fish. Daily activity patterns were based on the probability of detection, according to the time of day.

Detections were used to calculate the distance in meters between successive positions ($D_{A\rightarrow B}$):

$$D_{A\rightarrow B} = \sqrt{((Lon_A - Lat_B)^2 + ((Lon_A - Lat_B)^2)}$$

Where, Lon_A y Lat_A are the geographic coordinates (UTM) of the first position, and Lon_B and Lat_B are the final geographic coordinates.

The average speed of tagged fish was obtained on the basis of the time recorded between each detection (m s^{-1}). Subsequently, the distance covered by a fish during 24 h (m $día^{-1}$) was estimated on the basis of the total covered distance and the total monitoring time. The receiving equipment data bases were introduced into an SIG and were assessed with the Animal Movement Analysis ArcView Extension (Hooge and Eichenlaub, 1997). A layer with bathymetric information (SHOA map) was introduced into the SIG. The distribution area used by tagged fish was obtained by calculating an *ad hoc* parameter that considered 50% of the contour as the area of main activity (m^2) and 95% of the contour as the distribution area (Hooge et al., 1997). On the positions obtained within the study zone were used, except for the movements of fish that left the study area permanently. The geostatistic analysis and spatial representation of detections were made using ARCGIS 10.0 software. To represent the physical characteristics (that is, bathymetry, substrate type) of Tongoy Bay, thematic data coverage was developed by interpolation IDW (ESRI, 2011). In addition, the information provided by the receivers, related to the date and location (inside Tongoy Bay) of tagged fish was assessed using a Tracking Analyst Arc Editor 9.3. This tool allowed us to display, assess and understand spatial patterns and trends in the context of time.

RESULTS

Spatial and time patterns in the use of habitat in Tongoy Bay

A total of 2,039 flounders were landed during the study period, with a total biomass of 2,074 kg. Landings recorded of 113 fishing trips used gillnets in the study area. The records are related to 19 vessels that used 5.1 fishing hours obtaining an average catch of 12.1 individuals (~11.4 kg) by vessel.

Fishing zones varied depending on the time of year. Landing records obtained from December 2011 to January 2012 (austral summer) showed a higher catch volume in three fishing zones (4, 9 and 11). From April to July 2012 (autumn and austral winter) only landings from zones 2 and 3 were recorded. Landings were recorded from January to March 2013 (austral summer) from 5 fishing zones (2, 3, 4, 10 and 28).

The CPUE displayed statistically significant differences in the different catch periods ($F_{[3;68]}$=2.958; P=0.0384; Figure 7a). These differences were explained by differences in abundance recorded in spring and summer months. Length frequency distributions of Chilean flounder harvested throughout the entire study period displayed statistically significant differences ($F_{[3;2035]}$ = 4.4193; P=0.0042; Figure 7b).

Length ranges in fish harvested in the austral summer period (December 2011 - February 2012; January 2013 - March 2013) varied from 19 to 90 cm TL, with a larger length frequency at 35 cm. During the austral autumn months (April 2012 to May 2012) landed fish displayed lengths that ranged from 28 to 49 cm TL, with a higher frequency at 39 cm. In austral winter months (July 2012 to September 2012), the lengths of landed fish ranged from 31 to 62 cm LT, with a higher frequency at 38 cm. Moreover, in austral spring (October 2012 to December 2012) lengths of landed fish ranged from 28 to 64 cm TL, with a higher frequency toward 33 cm.

Throughout the study period, length frequency distributions of flounder landed at Tongoy Bay displayed statistically significant differences (KW test; $F_{[4;15]}$=10.3064; P=0.0003). A unimodal distribution was observed during each landing period (summer, autumn, winter and austral spring). In summer, the fish showed a

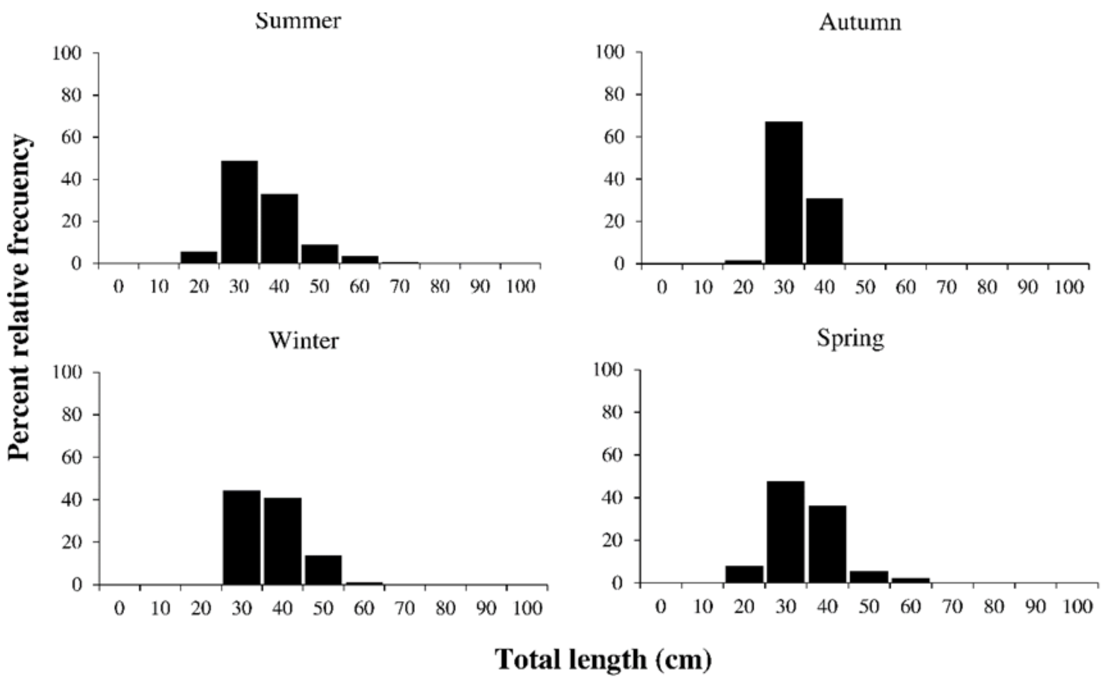

Figure 8. Length-frequency histograms of Chilean flounder (*P. adpersus*) captured in Tongoy Bay during the study period.

length frequency distribution with a main peak at 37 to 38 cm TL. In autumn, 67% of Chilean flounder measured <40 cm TL. During winter 85% of landings recorded lengths ranging from 31 to 49 cm TL. These lengths accounted for 81% of the catch in winter (Figure 8).

Relationship between CPUE and abiotic parameters

Mean water temperature was lowest in winter (13.37 ± 0.23ºC, mean ± SD) and highest in summer (17.34 ± 0.79ºC). The salinity in the Tongoy Bay ranged from 34.24 to 34.62 (S_A) during the autumn and winter months, respectively. The Chilean flounder were captured over a broad range of temperatures and depths (13-18ºC and 1.96-55.60 mt; Figure 9). Multiple regression analysis indicated a significant relationship between abiotic parameters and CPUE of *P. adpersus* ($F_{[3;68]}$ =4.0923; P< 0.001). For Chilean flounder, temperature exhibited a greater influence on CPUE than depth (standardized coefficient β = 7.82 vs -0.96, respectively), and salinity was dropped from the model since it did not contribute explanatory power.

Evaluation of Chilean flounder movement using mark-recapture

Out of the total tagged and released individuals (7,510) only a 17.67% (1,327) of flatfish were recovered. The highest number of recaptured fish was made using a trawl during a period of eight months (June 2012 to January 2013). The fishing zones with the highest proportions of recaptures with this fishing gear were 3, 4, 5, 9 and 11, characterized by fine sediment (Table 3). At the time of capture, the flounder had an average weight of 220.1 ±132.6 g and measured 31.1±1.6 cm TL. Visual examination indicated that the recaptured fish appeared to be in good condition. All were recaptured in different zone of the bay in which they were released. The minimum and maximum potential distances traveled by individuals ranged from 0 m (that is, they were caught within a trawl) to <4,000 m (Table 3).

Acoustic telemetry

Of a total of nine receivers anchored in Tongoy Bay during the study period, only six of them recorded the signals from the ultrasound transmission device implanted in twelve fish. During the study period, a total of 4,770 records were made, of which 50.8% come from a one receiver while the other records were obtained by five receivers.

An assessment of the information of the equipment anchored in the study area revealed that the highest number of records (3,285) was obtained in October, of which, 2 receivers showed the highest number of readings. Out of the total tagged fish (12) only 66.6% of them were recorded 6 of the 9 anchored equipment

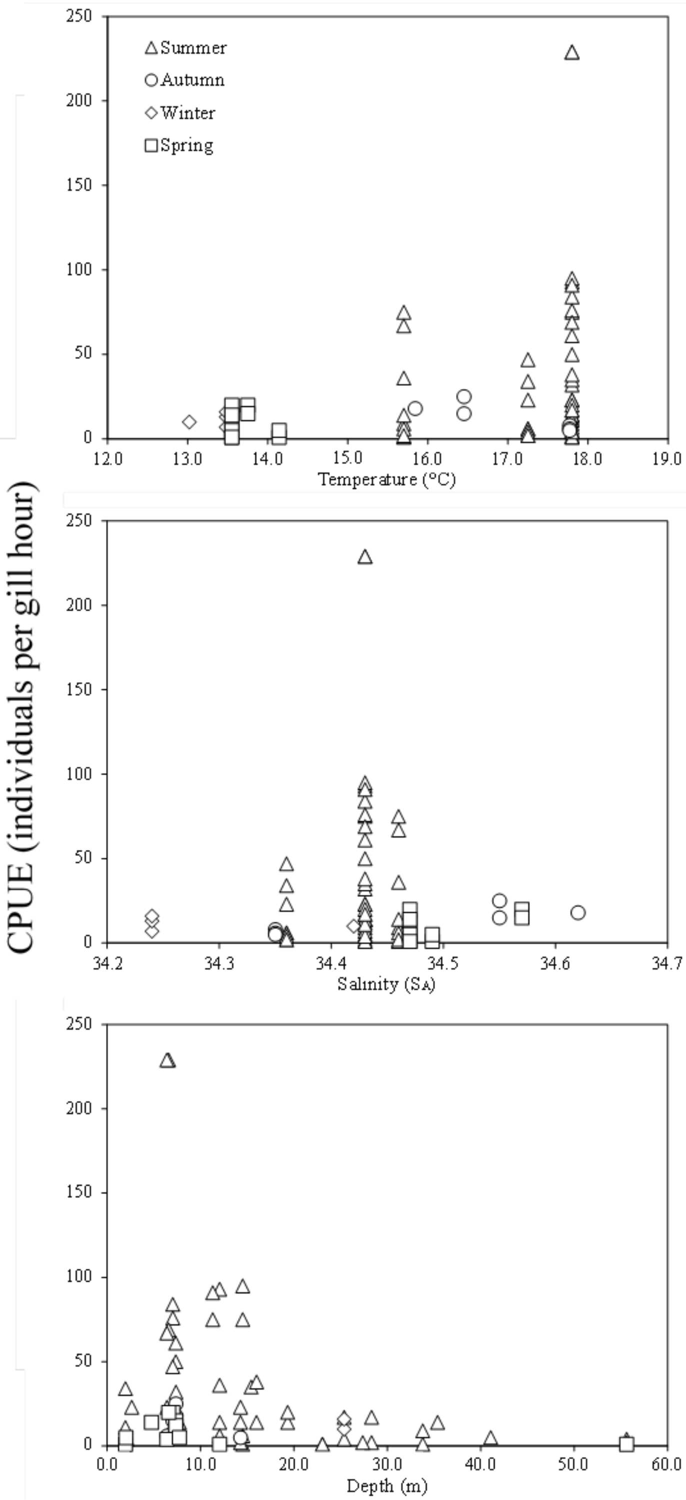

Figure 9. Catch per unit effort (CPUE, individuals per gill hours) of Chilean flounder vs abiotic parameters measured in Tongoy Bay during 2012.

(Table 4). In August 2012, the receivers recorded the presence of six fish (50%) with a total of 123 records (Table 4). The lowest records of tagged fish were made in October and December, 2012, and in January 2013. It is noted that in the months of June, July and September, 2012, the receivers did not record the presence of tagged fish.

Movement patterns of Chilean flounder in Tongoy Bay

The assessment of the landing records of Chilean flounder, added to data from the fish marked with elastomeric paint, and a spatial analysis of the total records obtained from the acoustic receivers during the study period, the presence of corridors and/or movement routs for juvenile and adult flounder were identified in Tongoy Bay.

Early juvenile stages (10-23 cm TL) displayed a movement mainly circumscribed to the coastline (limited to 5 m isobath), and associated to fine and very fine sandy bottoms. The movement track for this group of fish showed a preferential distribution area, with a higher frequency during the day and night, and mainly grouped in bottoms with seagrass (Figure 10).

Juvenile flounders displayed movements across a larger area of Tongoy Bay, compared to the previous group, extending from the coastline up to approximately 30 m isobath. The movement data assessment for this group of juvenile fish (25 to 34 cm TL) allowed us to establish a distribution area during the day and the night. The records indicated that juvenile flounder in this group increased their distribution area during the night within Tongoy Bay (Figure 11).

Adult flounder individuals (35 to 50 cm TL) monitored during the study period showed a movement track that covered the entire area up to 50 m isobath. A spatial analysis was made to establish an occupation area inside Tongoy Bay, and the location of a preferential zone for this group of fish during the night, which was different in terms of size and location from the two juvenile groups (Figure 12).

DISCUSSION

Patterns of habitat use into Tongoy Bay

The highest CPUE of Chilean flounder was found towards shallow areas of the bay near the shore. It is likely that spatial distribution patterns of juvenile and adults were influenced by the seasonal variations in the environmental conditions found among zones of the bay, as well as by recruitment and emigration events (Kramer, 1990, 1991b; Gibson, 1997; Fodrie and Mendoza, 2006). The results of the multiple regression analyses, coupled with the distribution and variable CPUE of Chilean flounder into Tongoy Bay, indicate that the temperatures

Table 3. Number of flatfish marked with paint marking and recovered during June 2012 - January 2013 into Tongoy Bay (Colors account for length classes with assigned color).

Color mark	Size fishes marked released (cm)	Number fishes released	Release zone	Size fishes marked recovered (cm)	Recapture zone of fishes marked	Number fishes recapture	Min. distance moved (m)	Max. distance moved (m)
Red	5.0 - 6.9	1,304	13	29.0 - 32.0	5	160	122	2,431
Pink	7.0 - 8.9	1,363	10	29.0 - 31.0	3	75	471	3,084
Orange	9.0 -10.9	1,319	13	-	-	-	-	-
Yellow	11.0 - 12.9	1,300	10	29.0 - 33.0	4	212	362	1,877
Green	13.0 - 14.9	1,300	10	30.0 - 35.0	11	93	748	2,335
Blue	15.0 - 16.9	924	13	34.0 - 36.1	9	18	200	900
Total		7,510				558		

Table 4. Monthly summary of records and presence of marked flounder in area covered by acoustic receivers.

Year	Months	Color mark	No.registers	Code signal receptor	Record duration
2012	June	Not recorded	-	-	-
	July	Not recorded	-	-	-
	August	Blue 1	25	1127422	0 h 28 min
	August	Blue 2	5	1130192	0 h 5 min
	August	Pink 2	2	1127425	0 h 3 min
	August	Green 1	8	1127424	0 h 32 min
	August	Orange 1	78	1130186	2 h 58 min
	August	Orange 2	5	1127423	0 h 36 min
	September	Not recorded	-	-	-
	October	Yellow 1	107	1130190	10 h 10 min
	October	Orange 1	1,349	1130186	95 h 0 min
	October	Green 1	1,829	1127424	131 h 0 min
	November	Blue 2	3	1130192	0 h 1 min
	November	Orange 1	631	1130186	33 h 3 min
	November	Yellow 1	106	1130190	19 h 0 min
	November	Green 1	1	1127424	0 h 10 min
	December	Orange 1	414	1130186	59 h 0 min
	December	Yellow 1	126	1130190	3 h 48 min
	December	Green 2	46	1130188	3 h 31 min
2013	January	Orange 1	31	1130186	3 h 55 min
	January	Green 2	2	1130188	0 h 20 min
	January	Yellow 1	2	1130190	0 h 20 min

and bathymetry that occur during the summer months drive habitat utilization patterns. Adults and juveniles were consistently caught throughout the system at temperatures and salinities that included the warmest and most saline conditions of the year (Figure 9; Álvarez-Borrego and Álvarez-Borrego, 1982). This is consistent with the tolerant nature of the juvenile stage of California halibut (Madon, 2002; Fodrie and Mendoza, 2006). We do not know studies that evaluate the tolerance level in adults and juvenile of Chilean flounder to temperature or salinity. The CPUE of Chilean flounder was significantly related to depth. The highest values were found in shallow water less than 7 m deep, and very few individuals were captured in water depths greater than 50 m. This agrees with previous studies on California halibut (Krammer, 1991b; Fodrie and Mendoza, 2006), which also identified a relationship between abundance and depth.

Evaluation of the mark-recapture strategy

The recapture rate for Chilean flounder (2.65%) is widely lower than that reported by Haaker (1975) (8.8 and 4.6%

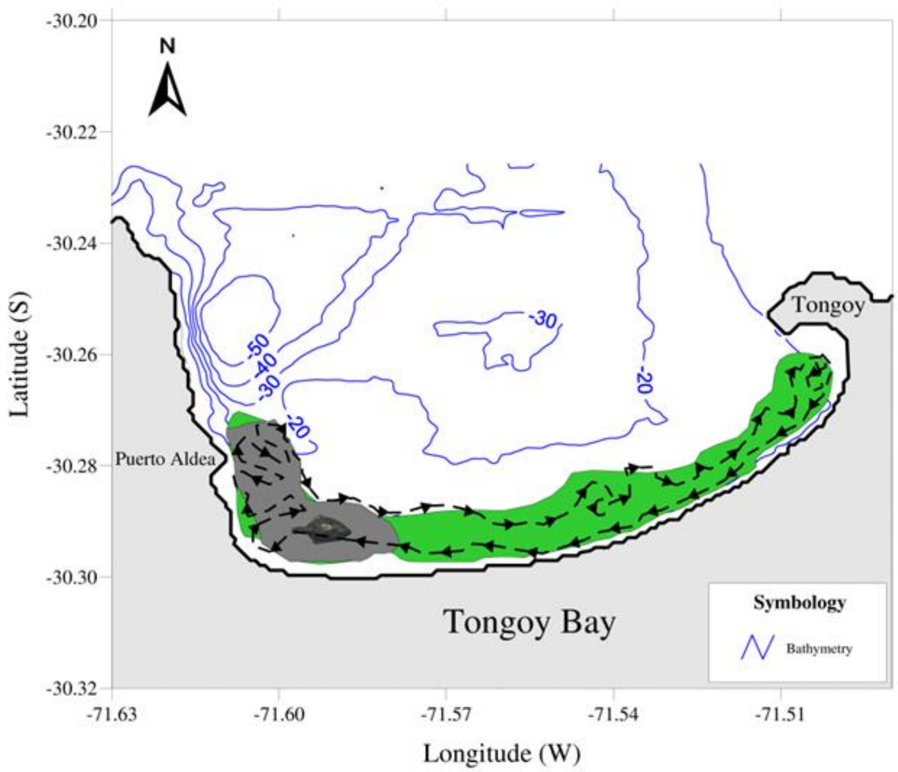

Figure 10. Movement track by early juvenile flounder and preferential distribution area for juvenile-early stages of flounder during the day (green) and night (grey) inside Tongoy Bay. The black line (segmented) indicates the used route.

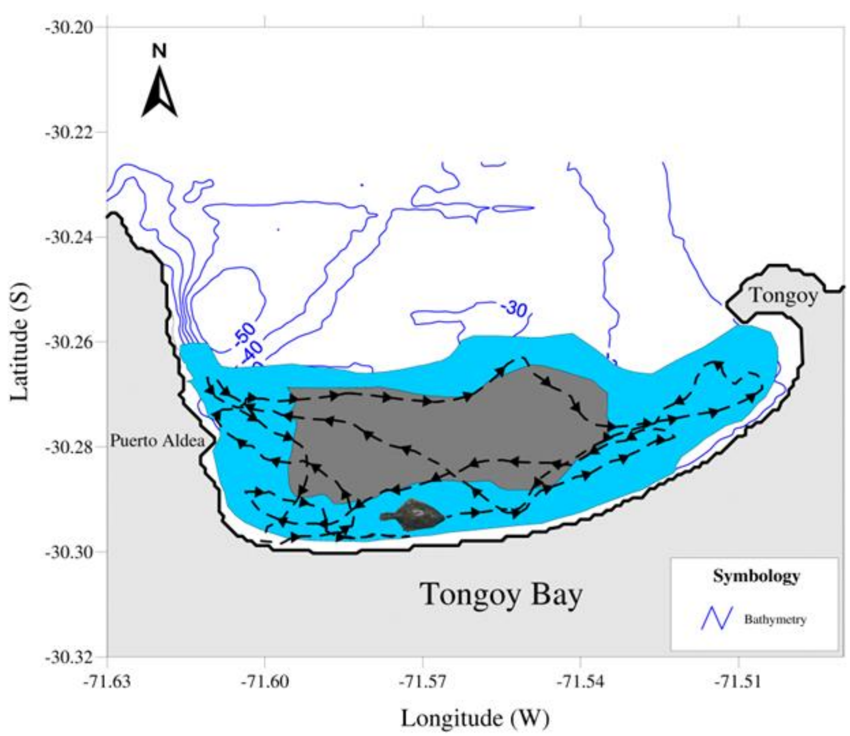

Figure 11. Movement track by juvenile flounder and preferential distribution area for juvenile flounder during the day (light blue) and night (grey) inside Tongoy Bay. The black line (segmented) indicates the used route.

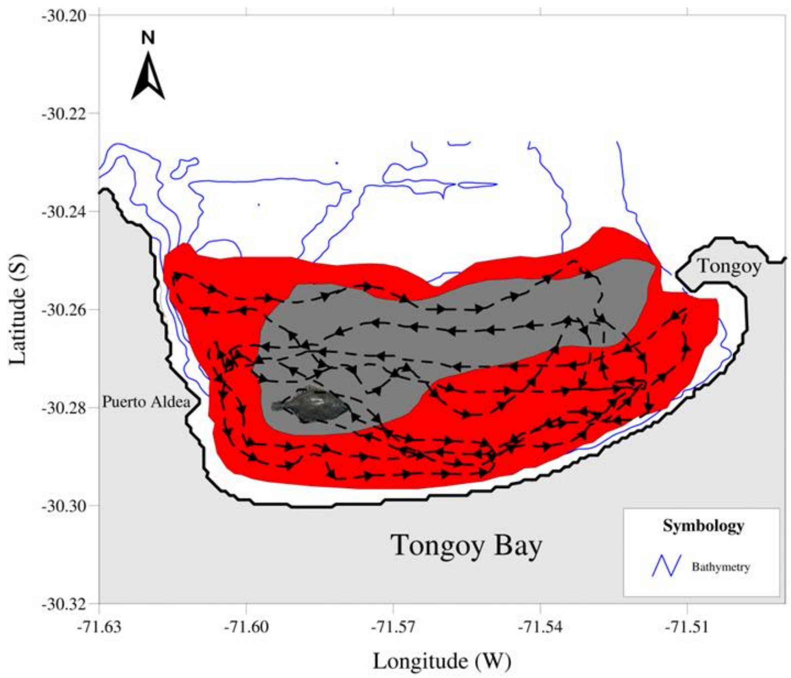

Figure 12. Movement track by adult flounder and preferential distribution area for adult flounder during the day (red) and night (grey) inside Tongoy Bay. The black line (segmented) indicates the used route.

using spaghetti clips and fin tagging, respectively), in a similar study conducted in Anaheim Bay. Comparatively, low recapture rates of Chilean flounder is similar to other studies performed on California halibut adults (Domeier and Chun, 1995; Posner and Lavenberg, 1999). The higher recapture rates obtained by other researchers may be related to differences in the sampling strategies employed to recapture tagged fish, including longer recapture periods and a more intensive recapture effort. The size-selective mortality of juveniles (Sogard, 1997) and the emigration of individuals out of the system may have also contributed to low recapture rates. One other possibility is that the tagging method used in this study was responsible for the low recaptures; however, the laboratory evaluation of the elastomer tags indicated that neither tag loss nor tag-induced mortality were substantial. VIE tags have also been used successfully in tagging studies involving black drummer (*Girella elevate*, Griffiths, 2002), common bully (*Gobiomorphus cotidanus*, Goldsmith et al., 2003), bridled goby (*Cryphopterus glaucofraenum*, Malone et al., 1999), and Atlantic cod (*Gadus morhua*, Olsen et al., 2004). Hence, it is unlikely that significant tag loss influenced these results.

Short-term movement of Chilean flounder in Tongoy Bay using acoustic telemetry

This is the first study that uses acoustic telemetry in Chilean flounder (*P. adpersus*) in their natural environment. There are experiences in the use of this type of technology with other flounder species (that is, *Pseudopleuronectes americanus*) with similar results, despite the higher time scale in such studies (DeCelles and Cadrin, 2010; Sagarese and Frisk, 2011).

The use of passive tracking allowed assessing the movement and presence of Chilean flounder (*P. adpersus*) near the coast. This species of flatfish remains in Tongoy Bay throughout the entire year, and the abundance of monitored individuals reached its maximum point in spring. Most fish do not leave coastal waters when the bottom temperatures exceed 15°C, unlike the behavior reported for the Winter flounder (*P. americanus*; McCracken, 1963; Howe and Coates, 1975; Phelan, 1992; Wuenschel et al., 2009). From October to November 2012, a total 84.4% were made when the water column temperature in Tongoy Bay began to increase (~14°C) to around 17°C in the summer period.

In contrast few fish were detected in winter (June-September), during the spawning period. In general, movement tracks displayed by flounder in Tongoy Bay revealed that individuals of this species are capable of living at great depths and occupying a greater area in the bay as they reach larger sizes. The movements of this species were classified according to the three most common movement patterns: (1) Movement of fish within the bay; (2) Dispersion of fish outside the bay (offshore), and (3) Connectivity with other coastal areas.

Residence patterns displayed by Chilean flounder (*P. adpersus*) in Tongoy Bay are consistent with the information reporting the use of shallow gulfs and bays with soft sandy bottoms as habitat, as well as to other flounder species such as *P. dentatus* and *P. californicus*, that search for protection from predators, more appropriate temperatures and abundance of food (Able et al., 1990; Kramer, 1991; Acuña and Cid, 1995).

Adult Chilean flounders showed increased activity within Tongoy Bay during the study period, possibly as a result of differences in lengths between the released individuals. Although the juvenile and adult flounder individuals showed differences in the space occupied into bay, this results must be interpreted cautiously because flounders possibly experiment changes in behavior after being implanted, especially those smaller sized individuals that may have with less movement capacity.

Evidence shows that the Chilean flounder species (*P. adpersus*) is present in Tongoy Bay throughout the entire year, although it is not clear if these individuals represent: (1) A single group within a stock; (2) A genetically different stock, or (3) a portion of individuals of a stock that shift to other locations outside the bay or remain within. To this regard, it is probable that a significant number of flounder from other adjacent bays constantly enter Tongoy Bay to spawn.

Although it has commonly been considered flounders shift toward the high seas near the coast when the temperatures increase during the summer period, it has been demonstrated that adult flounder individuals are capable of resisting warm temperatures by changing their behavior, which includes burying into the sediment, reducing their swimming speed and inactivity (Olla et al., 1969; He, 2003). In addition, flounders may escape the warm bottom waters and bury themselves up to 6 cm in the sediment, where the temperatures remain at more or less 4°C colder (Olla et al., 1969). Nevertheless, this behavior drastically reduces its detectability with the use of telemetry. Field tests indicate that the transmitters buried in the sand are detectable, but at a lower range, leading to a reduced detection area. Apart from burying themselves in the sediment, flounders can reduce their swimming speed or remain inactive to save energy (Olla et al., 1969; He, 2003).

The biotelemetry technique used in this research has great potential to study the movements and use of habitats of other species of commercial importance. Nonetheless, the movement track results of tagged flounders must be considered as preliminary. Future studies along the same line must necessarily include a higher number of tagged fish and improve the long-term viability of tags. In this regard, before carrying out field experiments in telemetry studies, it is important to determine the transmitter retention and mortality rates, and assess the variables that affect animal behavior (Pine et al., 2003; Fabrizio and Pessutti, 2007). The use of surgery is frequently a good option in long-term telemetry research, considering that the internally implanted tags may remain in fish during many years without any problem (Jepsen et al., 2002). Nevertheless, surgical implants are complicated and have been associated with a high risk of mortality, infection and loss of tags, all of which have been used as arguments in favor of external implants (Jepsen et al., 2002).

The results of this study provide valuable information regarding the movement of Chilean flounder in Tongoy Bay, which can help identify the possible causes of the general decrease of this resource, and may also serve as a platform for future research that deal with the ecological aspects of this species. Nevertheless, due to its preliminary character, they must be used with caution when managing the fish stock due to the information gaps that still exist to fully understand the population structure of this species.

Conflict of Interests

The authors have not declared any conflict of interests.

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