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SHORT NOTE

Early stages of notothenioid fish from Potter Cove, South Shetland Islands

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Abstract

At Potter Cove, King George Island/Isla 25 de Mayo, South Shetland Islands, significant ichthyological research has been conducted in the last three decades, mainly on the general ecology of notothenioid species in demersal stages from young juveniles to adults. Nevertheless, the knowledge of the ichthyoplankton composition in the cove, necessary for the overall comprehension of the dynamics of the fish species life-cycles, remained unexplored. Here, we report the first record of the early stages of Antarctic notothenioids collected in pelagic hauls at Potter Cove in summer 2014 and 2016 at depths of 6–9 m where total bottom depth ranged 30–190 m. The ichthyoplankton was represented by members of the families Harpagiferidae, Nototheniidae and Bathydraconidae. It consists of (1) 37 larval stages (preflexion and postflexion) of the species *Harpagifer antarcticus* (the most abundant), *Psilodraco breviceps*, *Lepidonotothen squamifrons*, *Pleuragramma antarcticum* and *Trematomus scotti*, and (2) 15 eggs of *Notothenia coriiceps*, of which two larvae hatched in the aquarium. Part of this material is illustrated by photographs. The presence of early life stages of fish in the cove is linked to the major influx from the Bransfield Strait and also depends on local environmental conditions (i.e., hydrologic, water circulation). In addition to being a spawning site for *Parachaenichthys charcoti*, already reported in the literature, nearshore localities of the South Shetland Islands such as Potter Cove appear to also be spawning sites for *N. coriiceps*, *H. antarcticus* and *Chaenocephalus aceratus*.

Keywords Antarctic ichthyoplankton · Notothenioidei · Larvae · Eggs

Introduction

Most studies on the early life history of Antarctic fish started in the decades of 1980 and 1990 (Kock 1992 and references therein). In the western Antarctic Peninsula, which included the South Shetland Islands, investigations have been carried out on the abundance and spatial distribution of the ichthyoplankton in relation to the distribution patterns of adult stocks and oceanographic conditions (Slosarczyk 1986; Kellermann and Kock 1988; Loeb et al. 1993; Morales-Nin et al. 1995; Catalán et al. 2008; among others). These studies have emphasized the importance of the Bransfield Strait as a nursery area for fish spawning in the Weddell and Bellinghausen Seas, and have reported that the early stages of fish are dominated by members of the Antarctic endemic coastal demersal group, the suborder Notothenioidei.

The complexity, structure and function of the food web of Potter Cove, in the South Shetland Islands, have recently been analyzed (Marina et al. 2018). In this ecosystem, significant ichthyological research has been conducted, mainly on the general ecology of notothenioid species in demersal stages from young juveniles to adults (summarized in Barrera-Oro and Casaux 2008; Moreira et al. 2014). It has been indicated that, in inshore waters such as this locality, the ecological role of demersal fish is more important than that of krill because these vertebrates are benthos and zooplankton consumers, and they are also common prey of other fish, birds and seals, thus linking lower and upper levels of the food web (Barrera-Oro 2002). Nevertheless, the knowledge of the ichthyoplankton composition in Potter Cove,

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necessary for the overall comprehension of the dynamics of the life-cycles of fish species, remained unexplored.

This is the first report of the occurrence of eggs and larvae of notothenioid species in ichthyoplankton samples collected at Potter Cove in late spring–summer 2014 and 2016.

Materials and methods

Study area

The South Shetland Islands Archipelago is located 450 miles southeast of Tierra del Fuego, extending in an ENE—WSW direction. The South Shetlands, which are of volcanic origin, have many islets and rocks off their northern coasts and none on their southern coasts. Potter Cove is the easternmost cove in King George Island/Isla 25 de Mayo (Fig. 1).

The study area is a coast of a gentle slope with a pebble beach and submerged rocks at depths less than 150 m in the internal cove and down to 190 m at the entrance of the cove (Schloss 1997).

The water entering Potter Cove comes from the Bransfield Strait, which is influenced by waters flowing from the Bellingshausen and Weddell Seas. The dominant current within the Bransfield Strait is towards the north-east, and the outflow passes around Elephant and Clarence Islands to enter the Scotia Sea (Clowes 1934; Loeb et al. 1993). A narrow stream of north-eastern current flowing from the Bellingshausen Sea occurs near the southern shores of the South Shetlands (Grelowski and Tokarczyk 1985).

In Potter Cove, the general circulation pattern follows a clockwise direction and is characterized by the inflow of deep waters from the northern coast and the outflow of surface waters, with water masses being affected by the melting of the Fourcade Glacier (Schloss 1997).

Sampling and laboratory procedures

Ichthyoplankton was collected at Potter Cove, King George Island/Isla 25 de Mayo, close to the Scientific Station "Carlini" (formerly named "Jubany"; 62°14′S; 58°40′W), in January–February and November–December 2014 and in November–December 2016 by means of pelagic trawls (net

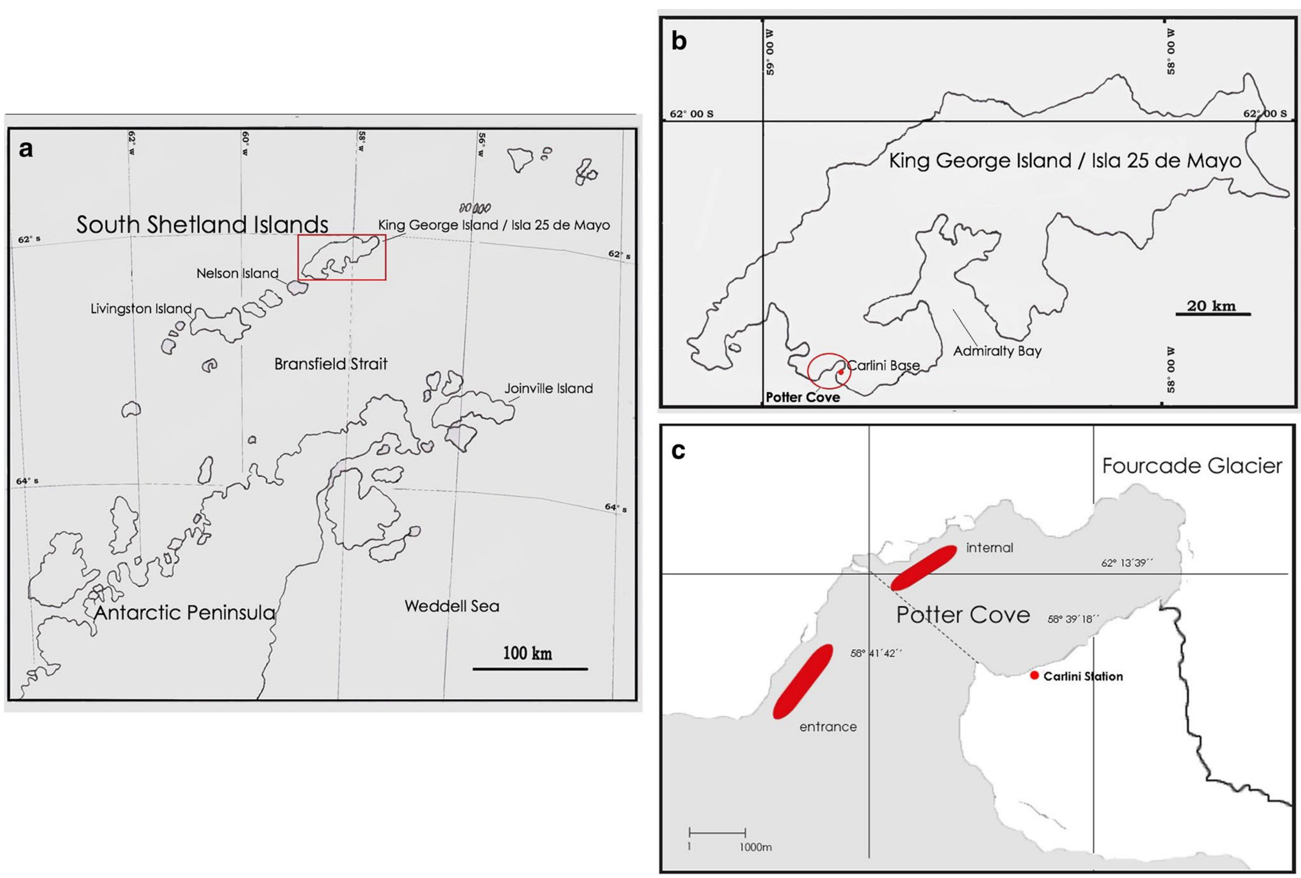

Fig. 1 General view of the South Shetland Islands and the Antarctic Peninsula (**a**) with enlargements of King George Island/Isla 25 de Mayo (**b**) and Potter Cove (**c**). *Shaded areas* in (**c**) denote the sampling areas

mouth 1 m^2, length 3 m, mesh 1 mm), which were operated from rubber boats (length 4.20 m) (Fig. 1). The net was towed during daylight at different hours from 1000 to 1730 hours (local time) at 2–2.5 knots speed from depths 2–9 m to the surface for 20 min. An average of 3 hauls per sampling date was carried out. After a fixing protocol, the samples were preserved in a final ethanol solution (70% ethanol, 20% H_2O, 10% glycerin) until they were processed. Total and standard larval length (TL and SL) and egg diameter were measured in mm. The details of sampling stations and fish collected are presented in Table 1.

The keys of Efremenko (1983) and North and Kellermann (1990) were used to identify the fish species at the different larval stages. We applied the terminology of Kendall et al. (1983) and Koubbi et al. (1990) to characterize larvae, and used that of Matarese and Sandknop (1983) to characterize eggs. For the nomenclature of the fish species, we followed Eastman and Eakin (2000), considering the revisions and synonyms proposed by DeWitt et al. (1990).

Results and discussion

This study constitutes the first record of ichthyoplankton at Potter Cove—37 larval stages and 15 eggs of notothenioid species—obtained in 17 of 95 hauls carried out (18%). The effectiveness of the capture per season was: January–February 2014, 9 of 41 hauls (22%); November–December 2014, 6 of 43 hauls (14%); November–December 2016, 2 of 11 hauls (18%).

It is known that notothenioid larvae are widely distributed in the upper 200 m of the water column and may undergone daily vertical migrations. The relatively low number of larvae and eggs collected in the shallower waters of Potter Cove may be due to limitations in our sampling procedure which was conducted to insufficient depth; the use of a relatively long gear towed by a small rubber boat under a preponderance of climatic constraints made us restrict the hauls just to the upper depth of 2–9 m.

The following species were represented: *Notothenia coriiceps* Richardson 1844 (=*N. neglecta* Nybelin 1951), *Harpagifer antarcticus* Nybelin 1947, *Psilodraco breviceps* Norman 1937, *Lepidonotothen squamifrons* Günther 1880 (=*L. kempi* Norman 1937), *Pleuragramma antarcticum* Boulenger 1902, and *Trematomus scotti* Boulenger 1907. These notothenioids have also been found in Admiralty Bay, in the vicinity of Potter Cove, and in Bransfield Strait, and comprises part of the demersal fish fauna of the West Antarctic Province (Kock 1992).

For the species that are rare as adults in the study area, e.g., *P. breviceps*, *L. squamifrons*, and *Trematomus scotti*, it should be clarified whether the presence of their larvae is occasional, depending on hydrologic and climatic factors. In fact, an annual-cycle study involving surface and bottom strata of the water column from two sites at Potter Cove showed that melting of the Fourcade Glacier, wind and pack-ice affect the temporal and spatial dynamics of micro and mesoplankton in terms of composition and abundance (Garcia 2015).

All the eggs found belonged to *N. coriiceps* and were collected at the entrance and interior of the cove at depths between 2 and 5 m. They ranged between 3.2 and 4.5 mm. Two eggs were placed in an aquarium on 13 December 2014 and from them, the larvae hatched 2 days after measuring 14 mm TL (Fig. 2). The eggs were similar to the advanced embryos described by Matarese and Sandknop (1983) and had the same basic pigment pattern described by Kellermann (1990). Our data of egg diameter and larval size at hatching are in general agreement with those reported in Kock and Kellermann (1991) for the species in the western Antarctic Peninsula (4.3–4.7 mm and 12.2–16.3 mm, respectively). The comparison of these eggs with early developmental stages of *N. coriiceps* from South Georgia that were obtained experimentally by White et al. (1982)

Table 1 Data of sampling stations and early stages of fish collected at Potter Cove

Haul[a]	Sampling date	Site in the cove	Depth of trawls (m)	Total depth to bottom (m)	Species collected	*n*	Stage
L 27, 28, 29, 31, 35,36,37	February 18, 19, 22, 2014	Internal	6–9	30	*Harpagifer antarcticus*	25	Larvae
L 38, 39	February 23; 2014	Entrance	6–9	190	*Harpagifer antarcticus*	6	Larvae
L 29	February 19; 2014	Internal	6–9	30	*Trematomus scotti*	1	Larvae
L 29	February 19; 2014	Internal	6–9	30	*Psilodraco breviceps*	3	Larvae
L 36	February 22; 2014	Internal	6–9	30	*Lepidonotothen squamifrons*	1	Larvae
L 37	February 22; 2014	Internal	6–20	30	*Pleuragramma antarcticum*	1	Larvae
L 1, 2, 17, 24, 38, 40	November 6, 30; December 5, 13; 2014	Entrance	2–4	190	*Notothenia coriiceps*	11	Eggs
L 2, 3	November 17; 2016	Internal	5	10–27	*Notothenia coriiceps*	4	Eggs

[a]Internal code

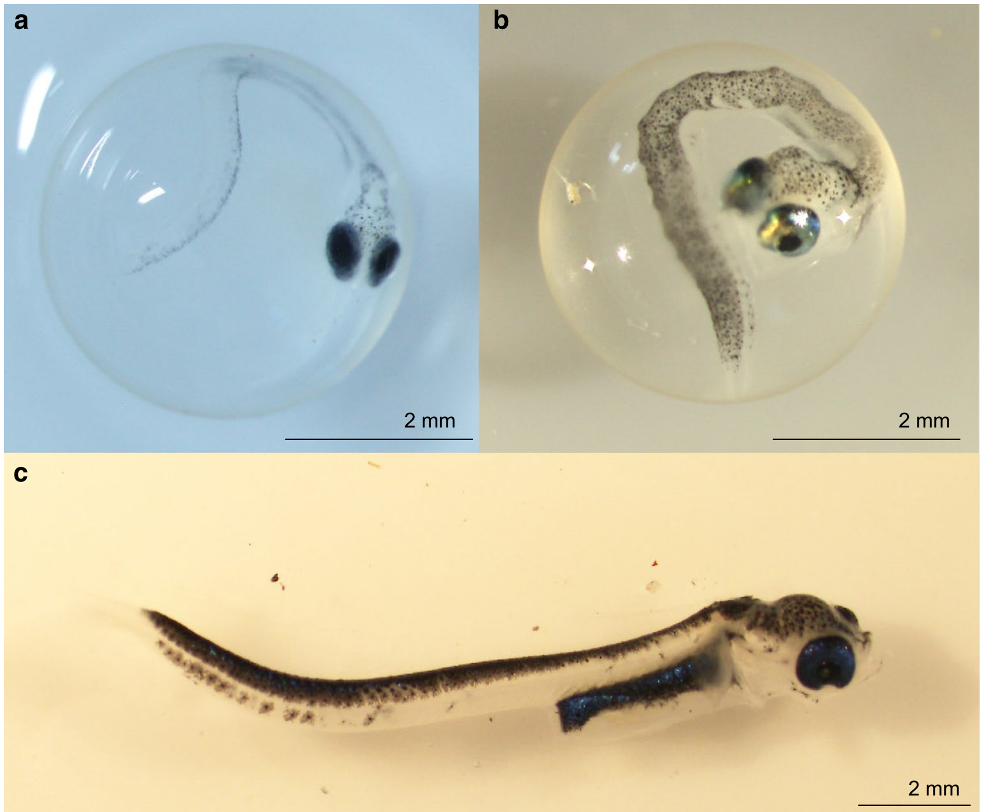

Fig. 2 Eggs of *Notothenia coriiceps* collected at Potter Cove (**a**, **b**) and larvae hatched in the aquarium (**c**)

showed that they corresponded to developmental stages of 58, 65 and 96 days embryo. The eggs placed in Carlini's aquarium developed into embryos densely pigmented on the dorsal part of the head and snout at hatch. Taking into account an incubation period of 150 days reported for the species at Elephant Island and the Antarctic Peninsula (Kock 1989; Kellermann 1990), we assume that the eggs collected in November were spawned in June–July. The larvae that hatched in our laboratory exhibited black eyes and a heavily pigmented body similar to the characteristics described by White et al. (1982) and Stevens et al. (1983). The presence of *N. coriiceps* eggs in the cove is not unexpected since this species is the dominant fish in inshore waters of the South Shetland Islands and the whole southern Scotia Arc (Everson 1970; Barrera-Oro and Casaux 2008). Males and females of *N. coriiceps* at maturing stage IV were previously reported at Potter Cove (Casaux et al. 1990) and in the Danco Coast, Antarctic Peninsula (Casaux et al. 2003), which suggested that spawning could take place nearshore. Sapota (1999) reported Admiralty Bay spawning of *N. coriiceps* in May and June and also the presence of eggs throughout the winter, although larvae were not found.

The most abundant species in every set at Potter Cove was the Harpagiferidae *H. antarcticus*, which was represented by 31 yolk sac preflexion larvae (stage 2) measuring 7–9 mm TL (mean 8.13 ± 0.77 mm) (Fig. 3). Of these, 25 were found in nearshore waters in the internal cove (total depth 30 m) and 6 in deeper waters at the entrance of the cove (total depth 190 m), all of them at 6–9 m deep. Their sizes fell within the range recorded for preflexion and flexion larvae collected in summer in the same season 2014 (SL = 5.97–10.66 mm; Landaeta et al. 2017) and also in 2015 (BL = 5.97–9.65 mm; La Mesa et al. 2017a) at Chile Bay, Greenwich Island, a nearby locality in the South Shetland Islands. Furthermore, these data are similar to the sizes of larvae at hatch (5–10 mm) collected from October to January in the Antarctic Peninsula (Kock and Kellermann 1991) and agree with the sizes observed in summer, between October

Fig. 3 Larvae of *Harpagifer antarcticus* collected at Potter Cove

and March (Loeb et al. 1993). *Harpagifer antarcticus* is a long-lived, slow-growing and nest-guarding species (Daniels 1983; White and Burren 1992). It occurs along the coasts of the southern Scotia Arc islands, the Antarctic Peninsula and subantarctic islands (Hureau 1990), and is abundant in inshore shallow waters under rocks and on muddy bottoms at depths from 3 to 6 m and also in tidal pools (Casaux 1998; Barrera-Oro 2002; Moreira et al. 2014). The finding of yolk-sac larvae of *H. antarcticus* in our samples together with the presence of bottom nests reported in the literature suggests that this species may spawn in nearshore areas such as Potter Cove.

The Bathydraconidae *P. breviceps* was represented by 3 postflexion larvae (stage 4) with yolk sac, a complete number of fin rays and finfold remnants. They measured 20, 23 and 25 mm TL, and were collected in 6–9 m deep in the internal cove.

Daniels and Lipps (1982) recorded fish of *P. breviceps* in summer 1975 in the Antarctic Peninsula at depths of 300–400 m and assumed that these fish did not belong to an established population in the region, but that they had dispersed from South Georgia. Kompowsky (1992) only found *P. breviceps* in shelf waters of South Georgia, where he collected 40 specimens at depths of 142–287 m in summer 1987–1989 with bottom trawls. However, in line with our findings at Potter Cove, 12 early juvenile specimens (TL 66–184 mm) of this species were caught in the nearby Admiralty Bay at depths of 146–540 m in November 1986 and February 1987 (Skóra and Neyelov 1992).

The remaining fish larvae collected at Potter Cove belonged to the family Nototheniidae. A 12-mm-TL preflexion larvae (stage 2) of *Lepidonotothen squamifrons*, a 30-mm-TL postflexion larvae (stage 3) with finfold remnants of *Pleuragramma antarcticum* and a 21-mm-TL flexion larvae (stage 1) with yolk sac of *Trematomus scotti* were caught in the internal cove at depths between 6 and 9 m.

Although no adults of *L. squamifrons* have been found in our study area (Barrera-Oro 2002), they occur in the Bransfield Strait at depths of 5–400 m (Catalán et al. 2008). Larvae *of Lepidonotothen squamifrons* are abundant during late spring and summer in the Antarctic Peninsula (Loeb et al. 1993), and have been caught in January–March in the South Shetland Islands (Efrementko 1983). This species is also present from early January onwards along the continental shelf in water masses influenced by the Bellingshausen Sea (Kellermann 1986).

The larvae of *P. antarcticum* were recorded in late spring and summer in the Antarctic Peninsula (Loeb et al. 1993) and in December–March in the South Shetlands (Efrementko 1983). Their presence during the summer in Admiralty Bay (Skóra and Neyelov 1992) was probably due to the high availability of Antarctic krill *Euphausia superba* (Barrera-Oro 2003), whereas their access to Potter Cove would be enabled with the entrance of waters from Admiralty Bay, together with large copepods, salps and jellyfish (Garcia 2015). This species has a circum-Antarctic distribution and its vertical range extends from 0 to 900 m (Gerasimchuk 1986), with all developmental stages occurring in the water column and specialized for pelagic life (Vacchi et al. 2004). In Antarctic waters, the notothenioid ichthyoplankton community is dominated by early life stages of *P. antarcticum* (Mintenbeck et al. 2012). Adults of this species are the most abundant fish in the coastal regions of high Antarctica (Duhamel et al. 2014) and are widely distributed around the Antarctic continent including Scotia Arc and adjacent islands (Vacchi et al. 2012).

Larvae of *Trematomus scotti* have been recorded in the western Antarctic Peninsula (Loeb et al. 1993) and nearby west of the South Orkney Islands (Skóra 1991). In the Bransfield Strait, Loeb (1991) observed that *T. scotti* was most abundant in the upper 100 m, but suggested that its distribution probably depends on physical processes and water mass movements; while Catalán et al. (2008) reported that it was abundant at depths of 5–400 m, mostly at 75 m deep. This species is primarily a benthic feeder with circum-Antarctic distribution, including the South Shetlands (Dewitt et al. 1990; Skóra and Neyelov 1992). In the Antarctic Peninsula and associated islands, hatching of larvae occurs in January, which suggests that the larval phase extends to winter (Kellerman and Schadwinkel 1991).

The fish fauna of the Bransfield Strait is composed mainly of notothenioid families of which early stages of Nototheniidae, Bathydraconidae and Harpagiferidae were represented in our samples at Potter Cove. Larvae and juveniles of Nototheniidae and secondarily of Channichthyidae have been the most commonly caught in the Strait (Kellermann and Kock 1988; Loeb et al. 1993; Morales-Nin et al. 1995; Catalán et al. 2008). This zone is a nursery area for fish spawning in the Bellinghausen and Weddell Seas (Kellerman and Schadwinkel 1991). For example, larvae–juvenile stages of the nototheniids *T. scotti* and *N. kempi* (= *L. squamifrons*) have been recorded in coastal areas of the Bransfield Strait, which are under the influence of transitional Bellinghausen waters (Catalán et al. 2008). The hydrographic complexity and climatic fluctuations in the adjacent South Shetland Islands region determines the composition, distribution and concentration of zooplankton assemblages. The studies conducted by Loeb et al. (2010) in both the Bransfield Strait and South Shetland areas, with multidisciplinary datasets collected from 1990 to 2004, allowed a comprehensive knowledge of the ichthyoplankton ecology. The ichthyofauna in Admiralty Bay was reported by Skóra and Neyelov (1992), who identified 35 species from 24 genera belonging to 10 families, including early juvenile to adult stages of the species represented in the present study at Potter Cove.

There is photographic evidence of nest-guarding behavior by Charcot's dragon fish *Parachaenichthys charcoti* at 30 m depth in February at Potter Cove (Barrera-Oro and Lagger 2010). La Mesa et al. (2017b) analyzed early stage samples of this species collected in the Bransfield Strait. They indicated an extended egg incubation period, a hatching timing from July to September, and a short pelagic larval phase of about 6 months that may last until the end of the first Austral summer. The absence of *P. charcoti* larvae in our samples, as well as those of other species that occur commonly in nearby areas (e.g., Admiralty Bay), may be linked to the rapid larval dispersal by local currents from the cove to deeper waters and/or to the limitations in our sampling procedures (e.g., insufficient depth coverage and effort time). Another punctual example was the absence of early stages of the channichthyid *Chaenocephalus aceratus*, of which several females at the maturity stage IV were recently collected in the internal Potter Cove (Novillo, personal communication).

In summary, the presence of early life stages of fish in Potter Cove is linked to the major influx from the Bransfield Strait and also depends on local environmental conditions (i.e., hydrologic, water circulation). Included in this premise are likely those fish species that spawn in the bottom at Potter Cove, such as *P. charcoti*, or that possibly spawn in nearshore waters like this locality, such as *N. coriiceps*, *H. antarcticus* and *C. aceratus*.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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