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Parasites of hoki, *Macruronus magellanicus*, in the Southwest Atlantic and Southeast Pacific Oceans, with an assessment of their potential value as biological tags

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ABSTRACT

The aims of the present study were to investigate the protozoan and metazoan parasite fauna of hoki *Macruronus magellanicus* in the Southwest Atlantic and Southeast Pacific and to identify parasites of potential value as biological tags for stock identification and migrations. In 2007 a total of 76 hoki were examined from three locations, two off the coast of Chile and one off the Falkland Islands. Two further samples were taken in 2009, one of 32 hoki taken from a position off the coast of Chile between those sampled in 2007 and one of 42 juvenile hoki taken off the Falkland Islands. Seventeen different parasite taxa were recorded, including eight identified to species. Seven were new host records for hoki, and at least three, and possibly as many as five, are new species. The most promising tag parasites for hoki stock identification are the long-lived larvae of the cestodes *Hepatoxylon trichiuri* and Pseudophyllidea gen. sp. and of the nematode *Anisakis* sp. Three others – the myxosporean *Myxidium baueri*, the nematode *Pseudascarophis* sp. and the acanthocephalan *Echinorhynchus longiproboscis* – were identified as potentially useful for following seasonal migrations of hoki and for estimating the proportions of fish of different origin in mixed samples.

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1. Introduction

Hoki, also known as Patagonian grenadier and long-tailed hake, *Macruronus magellanicus* Lönnberg, 1907, is an abundant pelagic fish distributed throughout the Southwest Atlantic and Southeast Pacific. It is of considerable commercial value to fisheries in Chile and Argentina, while its fishery to date is not well developed in the Falkland Islands. The stock in the Pacific seems to be highly depleted, while the stock in the Atlantic appears to be in good condition.

The distribution of *M. magellanicus* ranges northwards to 33° S in the Atlantic and to 29°16′ S in the Pacific Ocean, while they have been reported southwards to the tip of the South American continent at 57° S (Wöhler and Giussi, 2004). Between austral spring and autumn they are largely distributed in their feeding grounds south of 48° S (Wöhler and Giussi, 2004); in the winter they migrate further north for spawning. Large spawning aggregations have been found between June and August in close proximity to Guamblin Island off the Chilean coast between 43° and 48° S, while smaller aggregations of spawning fish and juveniles have been found in the Southwest Atlantic in the Gulf of San Matias and to a lesser extent in the Gulf of San Jorge (Wöhler and Giussi, 2004). The spawning aggregations of *M. magellanicus* in the Gulf of San Matias and Gulf of San Jorge cannot sustain the stock biomass observed in the Southwest Atlantic, so it has been speculated that an additional spawning ground may exist on the high seas in the Southwest Atlantic or that fish may migrate from the Pacific to the Atlantic.

D'Amato and Carvalho (2005) found no genetic evidence of different populations of hoki in the Southwest Atlantic, but Machado-Schiaffino and Garcia-Vazquez (2011) did find genetic evidence of at least two population units, one in the Southwest Atlantic and one in the Southeast Pacific, with perhaps two further subpopulations in the Southwest Atlantic with a north-south division. The hoki otolith chemistry analyses of Schuchert et al. (2010) suggested a high mixture of fishes indicating the existence of one stock with two spawning grounds around South America.

The identification of stocks is important to fisheries management because different stocks may be of different sizes and may exhibit different growth rates. Management strategies would have to be adjusted in the case of acceptance of the single-stock

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hypothesis. As it is intended to further develop and promote the hoki fishery in the Falkland Islands, it is of utmost importance to gain further understanding of stock structure, biomass and behaviour.

Deepwater pelagic fish such as hoki are extremely difficult to tag using mechanical tags because they do not usually survive the change in pressure inherent in bringing them to the surface. For such fish parasite tags can be a more useful alternative (MacKenzie and Abaunza, 2005). Parasites have been widely used as biological tags to provide information on the movements and population structure of their fish hosts (see Williams et al., 1992; MacKenzie and Abaunza, 2005). The ability to differentiate stocks on the basis of their parasites reflects the variations in ecological and environmental conditions in the regions that the hosts inhabit, resulting in non-uniform distributions and abundances of the parasites' final and intermediate hosts. Differences in feeding habits may also account for observed differences in infection between regions (Boje et al., 1997). A study by Oliva (2001) investigated the possibility of using metazoan parasites as biological tags for stock identification and migrations of hoki caught in different fishing areas off southern Chile. Oliva concluded that his parasitological evidence was not sufficient to consider the hoki populations in these two areas as different stocks, but that it did not preclude a migratory pattern from south to north.

The aims of the present study were to investigate the protozoan and metazoan parasite fauna of hoki in the Southwest Atlantic and Southeast Pacific and to identify parasites of potential value as biological tags for hoki stock identification and migrations. This was carried out in conjunction with work undertaken by the Falkland Islands Government Fisheries Department (FIFD) on the otolith microchemistry of hoki, to help elucidate their population structure in the study area (Schuchert et al., 2010). A recent study of the population biology of southern blue whiting, *Micromesistius australis*, in the same study area demonstrated the value of combining results from otolith microchemistry and parasite tags (Niklitschek et al., 2010).

2. Materials and methods

Samples of hoki were collected in 2007 during research vessel cruises from two locations in the Pacific off southern Chile and one from the Southwest Atlantic off the Falkland Islands (Fig. 1). The

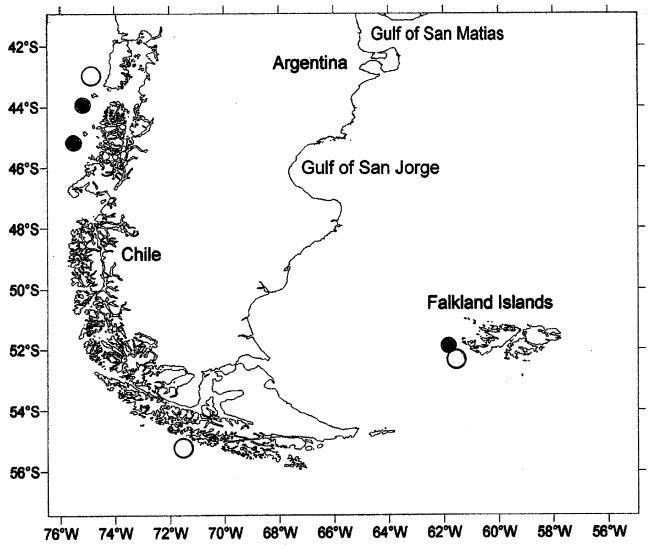

Fig. 1. Map showing hoki sampling locations. Open circles = 2007 samples; filled circles = 2009 samples.

Table 1
Numbers and lengths of hoki examined.

Position	Date	No. of hoki examined	Mean length (range) in cm
Falklands	October 2007	41	26.9 (25–29)
Chile (north)	June 2007	25	27.2 (23–30)
Chile (south)	October 2007	10	35.7 (27–42)
Chile	October 2009	32	44.6 (39–54.5)
Falklands	October 2009	42	21.4 (15–24)

Chile samples came from single hauls, whereas the Falkland Islands sample came from several hauls in the same area. A total of 76 fish were examined from these three locations (Table 1). The furthest north of the Chilean samples, taken off Chiloe Island in June 2007, was of spawning fish. The other Chilean sample, taken further south off Isla Santa Ines, and the sample from the Falklands, both taken in October 2007, were of feeding fish. Two further samples were taken in October 2009, one of 32 hoki taken from positions off the coast of Chile just south of the northern Chilean sample taken in 2007 and one of 42 juvenile hoki taken off the Falkland Islands. In the latter sample only the gall bladders were examined.

The otoliths of each fish were removed and a tissue sample was taken for genetic study. The gills, kidneys and viscera were removed and deep-frozen for later parasitological examination. All samples included the biometric and full station data for each fish. Following defrosting in the laboratory, the visceral organs were examined for parasites, free or encapsulated, on their external surfaces, then separated and examined individually. The stomach, pyloric caeca and intestine were separated and opened longitudinally. Squash preparations were made from the liver, spleen, kidney, gonads, intestine, muscle and brain, and scrapings from the urinary and gall bladders were examined for protozoan and myxozoan parasites using a compound microscope at a magnification of 400× under bright field and Nomarski interference contrast illumination. The gill arches were examined individually by scanning under a dissecting microscope at 20–40×, after which a scraping was examined under the compound microscope. Representative samples of each species of parasite encountered were collected for the FIFD reference collection and deposition in the Natural History Museum in London. Further samples of unidentified parasite taxa were also collected and stored, some in 10% formalin for morphological study, and some in 96% ethanol for molecular genetics.

The measures of parasitic infection used in this study were prevalence and intensity, as described by Bush et al. (1997). *Prevalence* is defined as the number of hosts infected with 1 or more individuals of a particular parasite species (or other taxonomic group) divided by the number of hosts examined for that parasite species, usually expressed as a percentage. *Intensity* is the number of individuals of a particular parasite species in a single infected host, while *mean intensity* is the total number of parasites of that species found in a sample divided by the number of hosts infected with that parasite. Because of the small numbers of fish in the samples, statistical analyses were limited to the Chi-squared test for differences in prevalence of different parasite taxa between samples, and the Mann–Whitney or Kruskal–Wallis tests for differences in intensity.

3. Results

Seventeen different parasite taxa were recorded, including eight identified to species. The list comprised one microsporidian, five myxosporeans, four digeneans, two cestodes, four nematodes and one acanthocephalan (Table 2). Seven of these parasites were new host records for hoki, and at least three, and possibly as many as five, are new species – the microsporidian, three of the myxosporeans and the nematode *Pseudascarophis* sp. Seven of the

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