Homing ability of goldsinny wrasse (*Ctenolabrus rupestris*) and corkwing wrasse (*Symphodus melops*)

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Abstract

Wrasse family (Labridae) are widely used as a cleaner fish in salmonid aquaculture to remove the sea lice infestation. Goldsinny wrasse and corkwing wrasse are the most used wrasse fishes in the aquaculture industry in Norway and since that the demand for wildly catching goldsinny and corkwing wrasse was increased and in 2017 it was the pick of the catching wrasse. In 2011, the first wrasse measurement regulation was established. After that, the fishery specified size limitations for all wrasses. The size limit for goldsinny wrasse is 11 cm, and for corkwing wrasse is 12 cm and with these size limits fishers can release them back to the sea, fishers may not always release fishes in the capture site. Homing behavior is the ability of fish to return at least one time to the same area that they recaptured. In my thesis, I examine the homing ability of goldsinny wrasse and corkwing wrasse by translocating 221 goldsinny wrasse and 116 corkwing wrasse which had been tagged earlier, to new locations 300m and 400m along the shoreline from their home and around the island with 400m far from their home and some of them released at the pier as a control group. In this study, the impact of the body length and sex in both species were tested as well. After translocation was done by detecting goldsinny wrasse and corkwing wrasse at the pier I observed that 90% of all goldsinny wrasse were translocated in 300m and 400m were returned home but 10% of them manage to return from the island. Among the corkwing wrasse, 10% of them return home from 300m and 400m from their home and there were no corkwing fish that returned from the island. In addition, goldsinny and corkwing had different return times. Goldsinny is faster than corkwing and goldsinny takes a long time to return home from the island, and corkwing takes more time to return from 400m distance from their home. In conclusion, for fisheries and management, my study suggests that both species can be released up to 400m along the same shoreline and most will still return to the home location. On the other hand, it is unclear what their fate is if we release them in open waters. Also, goldsinny wrasse showed homing ability when they returned across the open, deeper waters to go home from the island. In future studies, it is suggested to translocate goldsinny and corkwing to open waters in order to examine the homing ability.

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Preface

I am extremely thankful to my supervisor at University of Agder, Lars Korslund for his valuable guidance, constant support, enthusiasm, and his helpful suggestions along the way. I have learned so much and I'm very grateful.

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Additionally, I would like to thank Torkel Larsen for his support and patience, for teaching me how to recognize wrasse species and how to tag them with the PIT-tag. Thank you for helping me at the field work.

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1. Introduction

1.1. Homing

The concept of "homing" refers to returning to an individual's initial location that provides a suitable habitat for animals for feeding and spawning (Papi, 1992). The definition of homing is fish decision to return to previous habitat rather than go to other equally probable sites. (Gerking, 1959).

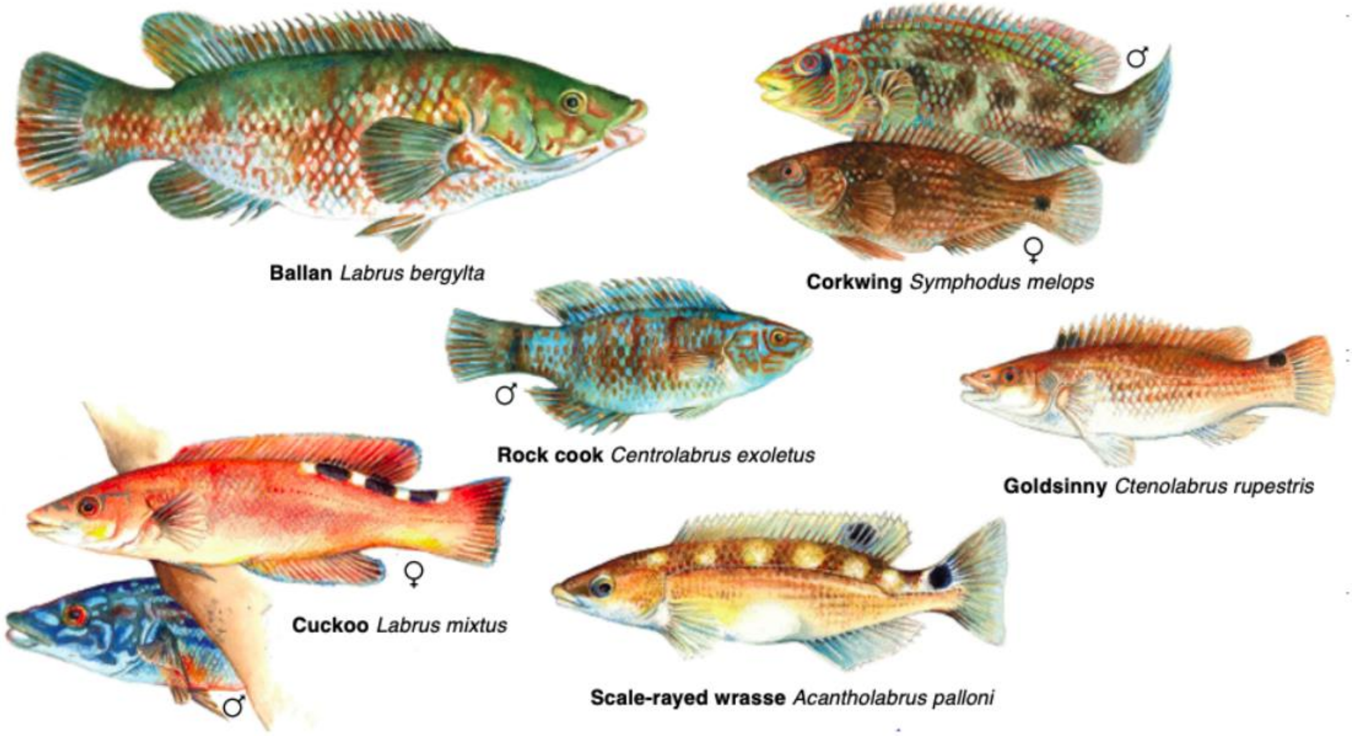
1.2. The wrasse (Labridae) family

Wrasse (Labridae) comprise a family of marine fish that is the second biggest in the world(Nelson, 1994), with at least 60 genera (Parenti & Randall, 2018) and over 500 species that live on brilliantly colored reefs (Helfman et al., 2009; Nelson, 1994). The wrasse family is widely distributed throughout the Mediterranean, along the north-western coast Europe(Quignard & Pras, 1986), and along the north-western coast of Africa to Norway in the Atlantic, Indian and Pacific Oceans (Costello, 1991). The five species of the wrasse family that are very common in Norwegian waters are goldsinny wrasse (*Ctenolabrus rupestris*), corkwing wrasse (*Crenilabrus melops*), ballan wrasse (*Labrus bergylta*), rock cook wrasse (*Centrolabrus exoletus*), and cuckoo wrasse (*Labrus mixtus*) (Costello, 1991). The scale-rayed wrasse (*Acantholabrus palloni*) (Risso) is a species of the wrasse family that lives in water depths between 50 and 270 meters; its habitat is also found along the Norwegian coast. (Costello, 1991) (Figure 1).

Wrasse are reef-dwelling fish that can be found abundantly near inshore areas with seaweed and algal-covered rock (Quignard & Pras, 1986). Rock cooks can be found near rocky coasts in sheltered areas (Thangstad, 1999).

Other wrasse types include the cuckoo, which may survive at depths of up to 200 meters, and the ballan, which can live near the shore and in deep waters surrounded by rocks (Costello, 1991). Wrasse feed on crustaceans and mollusks, which are shelled invertebrates (Costello, 1991), and they are a significant food source for large fish like cod, pollack, (Salvanes & Nordeide, 1993), and marine birds (Olsen et al., 2019).

Some types of wrasse, for instance rock cook wrasse and corkwing wrasse, have the shortest life spans of 9 years (rock cook) or less (corkwing); the life span of goldsinny wrasse is around 16 years, 11 years for cuckoo wrasse and 15 years for ballan wrasse (Halvorsen et al., 2016; Treasurer, 1994)



There are the six wrasse fishes were shown here with their gender;(female on bottom and male on top), rock cook, goldsinny, cuckoo (female on top and male on the bottom), and scale-rayed wrasse (rare species in wrasse family). Illustration by Stein Mortensen and modified by Marthe Ruud with permission.

Ballan wrasse is the largest type of wrasse, reaching a maximum size of 60 cm, whereas other wrasses reach maximum sizes of 38 cm (cuckoo), over 22 cm (corkwing), over 16 cm (goldsinny), and 13 cm (rock cook) (Costello, 1991; Halvorsen et al., 2016; Halvorsen, Sørdalen, et al., 2017).

The spawning season for wrasses normally lasts from spring to summer, depending on the species and geographical location (Costello, 1991). According to Darwall, et al. (1992), in the United Kingdom, spawning times vary according to wrasse family; goldsinny and corkwing wrasses spawn from April to September, rock cook wrasse spawn from May to August, and ballan wrasse spawn from April to August (Darwall et al., 1992). The majority of wrasse species are territorial (Costello, 1991), and in breeding season, dominant males defend their territory in the populations (Sjolander et al., 1972; Skiftesvik et al., 2014). Some females and subadults can become territorial after the spawning season. A single male goldsinny can defend its territory for several years, although a male corkwing wrasse prefers to protect only the region that is related to its nest (Costello, 1991).

Many wrasse species have complex reproductive strategies, such as sneaking behavior, female mimicry, or sequential hermaphroditism. Males are normally the larger sex (Halvorsen et al., 2016). Two of the five wrasse species are protogynous hermaphrodites, while the three smaller wrasse species are gonochoristic (Dipper & Pullin, 1979). Protogynous species act first as females, then change their sex and act like males, while gonochoristic individuals do not change their sex at all (Costello, 1991). Ballan wrasse mature as female when their body length reaches 22-24 cm and change sex when they reach around 32-40 cm in length (Skiftesvik & Halvorsen, 2019), whereas cuckoo wrasse change sex when they reach around 29 cm in length (Costello, 1991).

Corkwing and goldsinny wrasses have a secondary male strategy (Dipper & Pullin, 1979). These non-territorial accessory males are smaller than territorial males and adopt a sneaky behavior to fertilize eggs (Costello, 1991; Uglem et al., 2000). Accessory males occasionally join territories with spawning pairs, (a behavior known as "sneaking"), and they can also follow females in a dominant male's territory, attempting when doing so to pair with the females (Costello, 1991; Warner et al., 1975).

Most of the wrasse species have sticky benthic eggs which lie in the nests, and they are guarded by the male among the wrasse family. The goldsinny wrasse is the only species that has a planktonic egg (Darwall et al., 1992). The larvae of the wrasse family feed on zooplankton and grow to around 9-10mm in length before developing adult characteristics (Russell, 1976).

1.3. Goldsinny

Goldsinny (Ctenolabrus rupestris) is the smallest wrasse species and is, found in the eastern Black Sea and along the eastern Atlantic shores stretching from Morocco to the northwestern coast of Norway (Costello, 1991; Sayer, 1999). The maximum age for female goldsinny is 20 years; for male goldsinny, it is 14 years (Sayer et al., 1995). The maximum body length of goldsinny is approximately 16cm-18 cm (Darwall et al., 1992; Sayer et al., 1995). The normal habitat for goldsinny is an algae-covered shelter area above the substrate, rocks with shelter holes and kelp on top (Costello, 1991; Hilldén, 1984). The goldsinny wrasse feeds on amphipods, mollusks, crustaceans, and polychaeta, and was discovered at depths of 50 meters in the summer (Sayer et al., 1995). Adult goldsinny may be found in deeper waters than the juveniles (Sayer & Costello, 1996).

Goldsinnies may be distinguished from other wrasse species by the presence of a black spot at the base of the tail and black eye spots on the anterior part of the dorsal fin (Costello, 1991; Hilldén, 1984). Throughout the year, male goldsinny have a reddish spot on their flanks, which turn gold during spawning season. A female goldsinny wrasse is distinguished by vertical bands in the mid-ventral region and a black cloaca (Hilldén, 1984; M. Sayer, 1996) (Figure 2).

Figure 2: A) Male goldsinny with golden-orange lines on its flanks. B) female goldsinny with vertical lines in its mid-ventral area and a black cloaca. Photo: Neginasadat Neghabat.

Male goldsinny guard territories during spawning season, while females perform home ranging (Hilldén, 1984), Each territory was discovered in rocks with holes and algae at depths ranging from 0.5 - 10 meters(Hilldén, 1981). During the spawning season, male and female goldsinny wrasses are territorial; territories are normally guarded by one male and several females, with an occasional accessory male. Males seldom leave their territory after the reproductive season is over (Sayer, 1999), and one territory is always located in one area for several years(Hilldén, 1981). Adult goldsinnies have a high site fidelity, which they use to defend their small territory; they always return to their territory(Hilldén, 1981; Sayer et al., 1993).

Goldsinny wrasses release pelagic eggs, which descend to the bottom quickly after spawning, with only about 10% remaining on the surface. As a result of this trait, they are broadcast spawners(Darwall et al., 1992; Hilldén, 1984; Thangstad, 1999).

The majority of goldsinnies are seasonal, meaning they are active throughout the summer and then hide behind the refuges during the winter(Sayer et al., 1996). In addition, both male and female goldsinny make a short migration to deep water in the winter and then return to shallow water in the spring when the water temperature is rising (Hilldén, 1981; Sayer et al., 1993; Skiftesvik et al., 2015).

1.4. Corkwing

The corkwing wrasse (*Symphodus melops*) is found all along the Norwegian coast; it is also found, in the Skagerrak, Baltic Sea, and the waters along Morocco's eastern Atlantic coast (Knutsen et al., 2013; Sayer, 1996). Corkwing wrasses live in locations that are covered with algae, such as eelgrass beds or kelp forests, and they are plentiful along rocky coasts (Costello, 1991; Sayer, 1996). Corkwings can be found in shallow water at a depth of less than 5 meters (Halvorsen et al., 2020)

Female corkwings are smaller than territorial males but larger than accessory males for their age (Darwall et al., 1992). The most important prey for corkwing is the great variety of bivalves, copepods, and larvae of Chironomidae(Alvsvåg, 1993).

Corkwings are easily identified by the black spot in the middle of the base of their tail or under their lateral line (Sayer, 1996). They also have a comma-shaped area that is black behind the eye and dark horizontal lines along the length of their body; these marks are sometimes hard to distinguish (Costello, 1991). The general color of the corkwing's body is blue-green or olive green. A mature female has a blue genital papilla, which makes it easy to distinguish females from males. The female's body color is either blue-green or green with brown makings (Costello, 1991; Potts, 1974). Mature males have a reddish-brown body color with a red and blue pattern on their heads (Sayer, 1996). The color of the corkwing's body can change according to the spawning season, sex, and maturity (Sayer, 1996).

During the spawning season, territorial males build a nest with seaweed and algae; they strongly defend their nests (Potts, 1984). Some female corkwings spawn in the nest after it is built, and the benthic eggs are fertilized by accessory males before hatching in 3 - 12 days (Costello, 1991). In comparison to nesting males, these sneaker males grow slower and mature earlier (Halvorsen et al., 2016; Uglem et al., 2000). Sneaker males have a larger proportion of nesting males in high-density populations than nesting males. (Halvorsen et al., 2016).

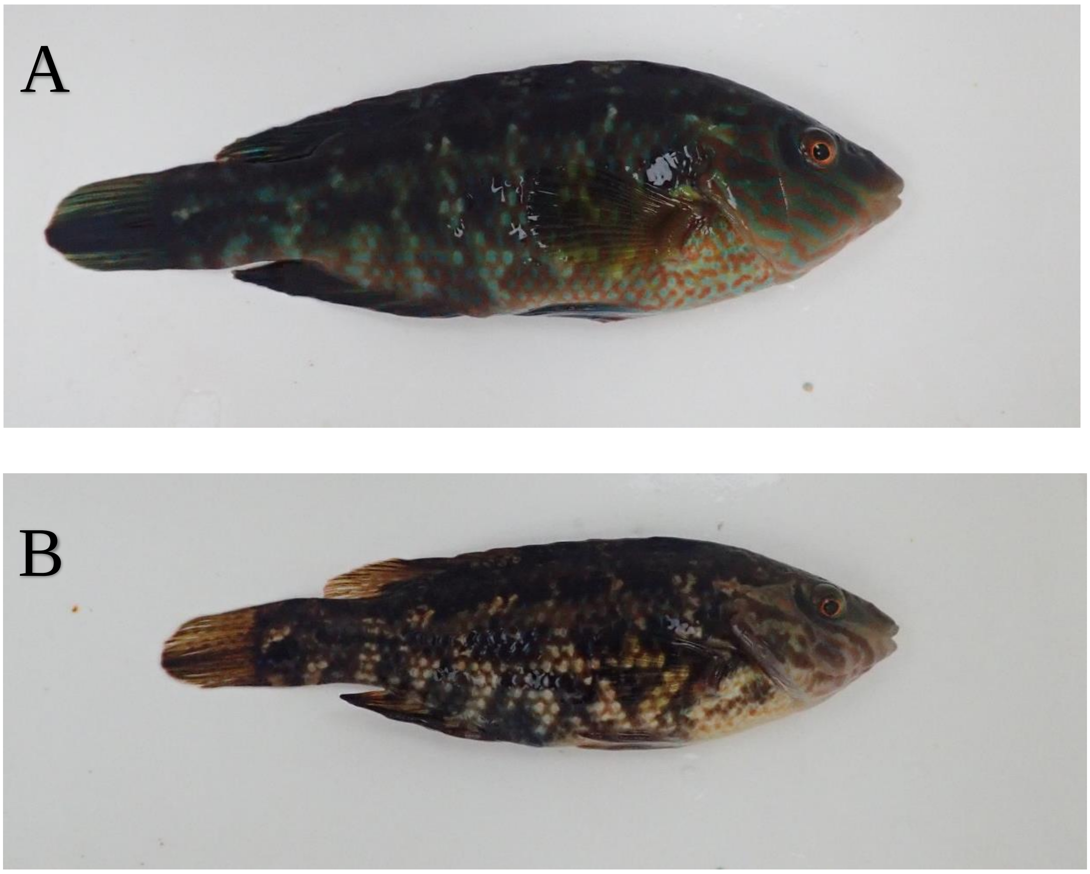


Figure 2: A) Male corkwing with brown color and the blue stripes. B) Female corkwing with dull green or brown color and dark blue urogenital papilla. Photo: Neginasadat Neghabat.

1.5. The wrasse fishing industry in Norway

Some wrasse species have developed cleaning symbioses with other kinds of large fish, and wrasses were first used as cleaner fish for Norwegian salmon farms in the late 1980s to eliminate salmon lice (*Lepeophteirus salmonids*) following a successful experiment done by Bjordal in the 1980s (Bjordal, 1988; Costello, 1996; Gjøsaeter, 2002; Skiftesvik et al., 2015). Lice infestations are a severe problem all around the world; in the past, chemical pesticides such as Neguvon were used to treat lice infestations, which had severe effects on salmon and placed them under stress (Bjordal, 1991).

The use of wrasses as cleaner fish in Norwegian salmon farms increased gradually from 1988 - 1997, but from 1998 - 2005, demand for wrasse decreased owing to the chemotherapeutic industry's increased reliance on delousing salmon (Bjordal, 1988; Darwall et al., 1992). Salmon lice finally lost their resistance to chemical pesticides in 2009; subsequently, demand for cleaner fish increased (Besnier et al., 2014). In Norway, the wrasse landing statistics increased from 2013 - 2017, reaching a maximum of 27 million in 2017(Norwegian Directorate of fisheries, 2022).

In Norway, four different wrasse species are being targeted as a cleaner fish goldsinny, corkwing, rock cook, and ballan (Halvorsen, 2017). Goldsinny and corkwing wrasses are the most widely used cleaner fish in the Norwegian aquaculture industry (Blanco Gonzalez & de Boer, 2017). Due to the increased demand for cleaner fish in Norway, the first wrasse measurement regulation was established in 2011(Norwegian Directorate of fisheries, 2022). While the fishery specified size limitations of 11 cm for all wrasses in this regulation, it was revised in 2015. As a result, the size limits were species-specific, with corkwings at 12 cm, ballans at 14 cm, and goldsinnies and other wrasse fishes at 11 cm (Halvorsen, Sørdalen, et al., 2017).

Due to the Norwegian aquaculture industry and use of wrasses as cleaner fish, millions of wrasses are harvested and translocated to other areas. Fishers catch fish and sex and size selectively, translocating the rest of the fish to other areas. Fisheries must know whether or not translocated wrasse fish will return to their original habitat.

1.6. Aim and objectives

The main goal of this study is to examine the homing ability of both goldsinny wrasse and corkwing wrasse. In the previous study by Starbatty (2021) homing ability of goldsinny was examined in three locations: at the pier, 100m and 300 m away from their home. The majority of these goldsinny managed to return home (Starbatty, 2021). In my research, the first objective is to examine return probability. To do this, goldsinny wrasses and corkwing wrasses will be translocated at the pier, at points 300m and, 400m away from their home, and at an island which is 400m away from their home. There will then be the opportunity to see whether they have the ability to go home.

The second objective is to examine return time which means examining the time it takes for corkwing wrasses and goldsinny wrasses to return home from the date they have been translocated. them. I will also observe whether covariant of sex and length affect homing probability and return time.

The reason that goldsinny wrasse and corkwing wrasse have been chosen for this study is that these two wrasse species are the most common cleaner fishes used in salmon farms in the Norwegian aquaculture industry.

2. Methods

2.1 Location

The research was carried out close to the Institute of Marine Research (IMR), in Flødevigen on the island of Hisøy (58º 25'N, 8º 45'E) facing the Skagerrak in southern Norway (Figure 3). This is located within a Marine Protected Area (MPA), and since 2017, commercial wrasse fishing using equipment such as fyke nets, pots, and nets has been prohibited. (Norwegian Directorate of Fisheries, 2021).

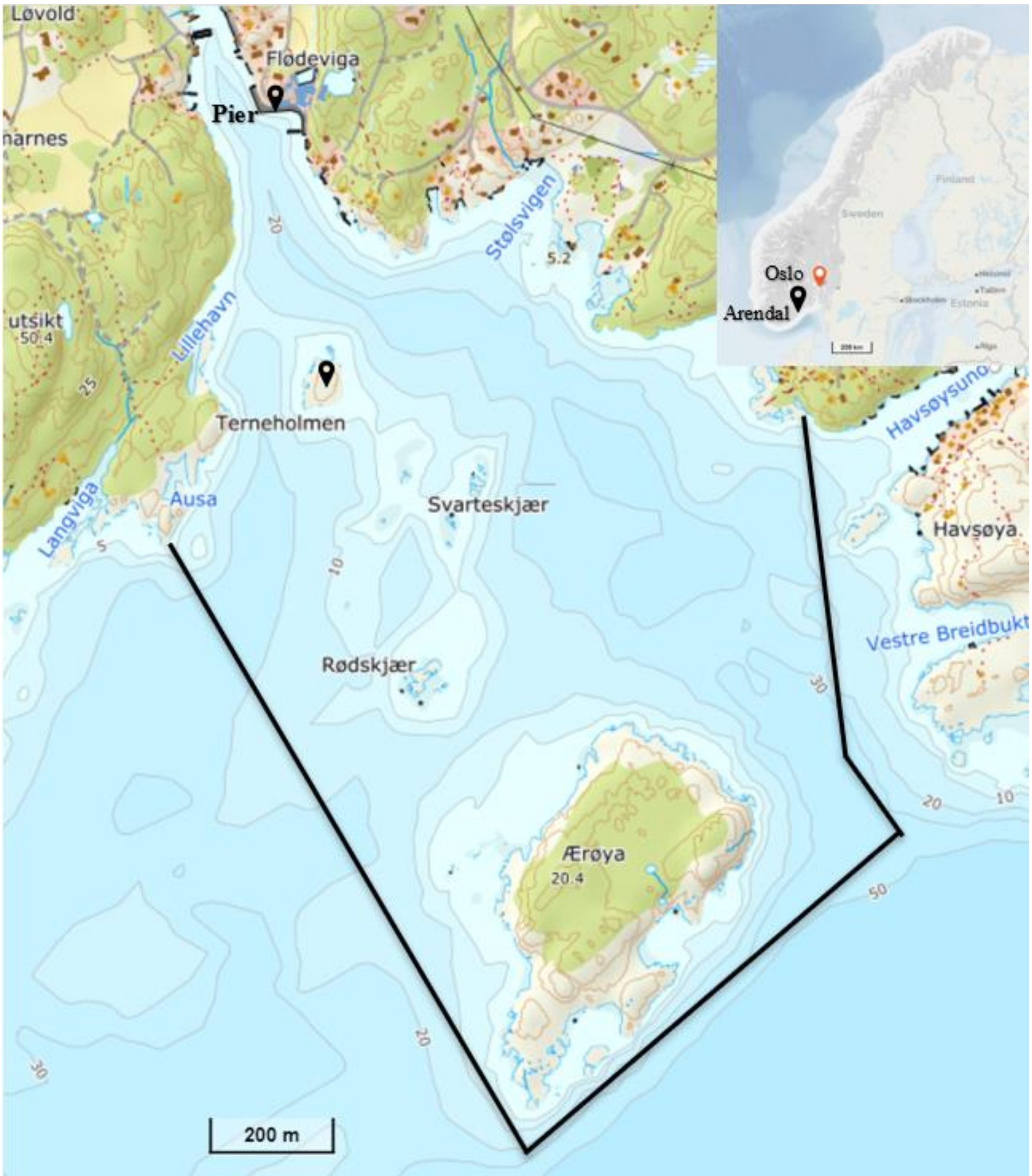


Figure 3: *Map showing research location in southern Norway and the boundaries of the marine protected area in Flødevigen (black lines).*

The pier of the research station is located inside Flødevigen. The bay's shoreline has a rocky substrate with plenty of brown algae, kelp, and seaweed, making it an ideal habitat for corkwings and goldsinny. The center of the bay has a soft substrate covered with sand and clay, making it less suitable for wrasse to live there. There are numerous small islands and rocks inside the MPA area. Terneholmen is the innermost of these islands, located 400m south of the pier in Flødevigen.

2.2 Capture and tagging of wrasse

The study was conducted from April 27th - November 5th, 2020. A scientific fishery of goldsinny and corkwing wrasses was carried out in four phases, each during one of four distinct sessions: 1) tagging and recapturing from April 27th - May 29th. 2) tagging August 7th - 14th .3) translocation August 14th. 4) recapture to detect homing from August 19th - 24th and October 27th - November 5th (Figure 4).

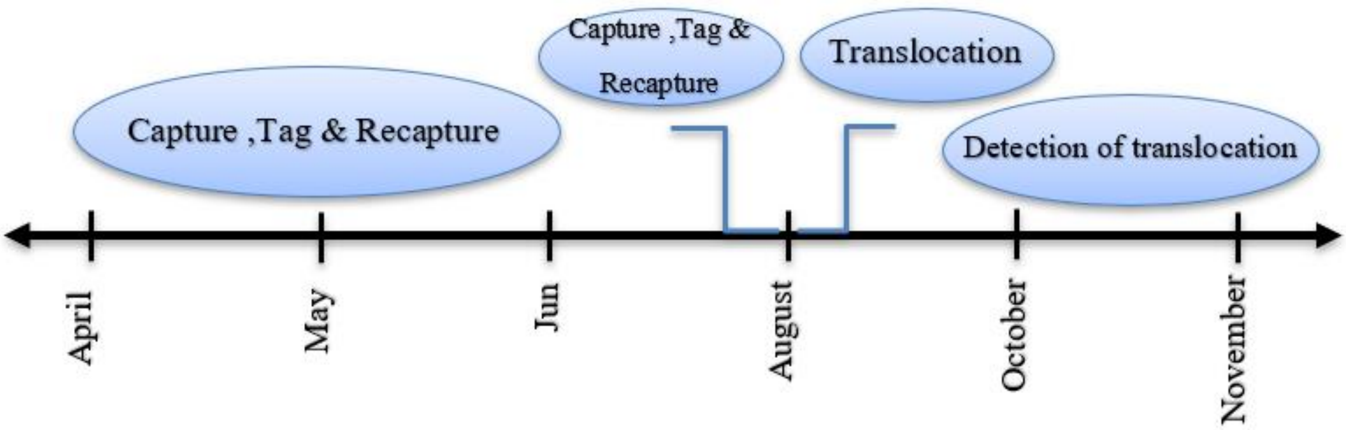


Figure 4: *A summary of the sample period separated into four sessions, as well as the dates for each session.*

The wrasse pots used throughout the study were set at a depth of more than 7 m on rocky substrates and covered with kelp. The pots (rectangular prism-shaped), measured 70cm × 40cm × 29cm, were equipped with two 75mm diameter circular entrances, and two chambers and were covered by 15 mm mesh (Figure 5). They were baited with shrimp and set in the afternoon;

they were then hauled up the next day (soak period: 15-28 hours) during all sampling periods. Pots were hauled up and inspected at random every second. Each fish caught was identified according to its species.

Goldsinny wrasse have a black spot on their dorsal fin; their other black spot is on the dorsal edge close to the caudal fin. Corkwing wrasses were recognized by the dark spot that is located on their caudal peduncle (Sayer, 1996). Although both male and female goldsinny have similar appearances, males have red or orange patches, or lines, on the lower part of their abdomen behind the pectoral fins (Halvorsen, Larsen, et al., 2017). Females possess vertical lines in their mid-ventral area (Sayer & Costello, 1996).

Female corkwings have a brown-green coloration, they also have a blue urogenital papilla, which distinguishes them from males. Corkwing nesting males have a different range of colors, including orange, brown, red, and deep purple-brown, with a brightly colored head (Halvorsen, Larsen, et al., 2017).

Figure 5: *On the left two wrasse pots were used to capture goldsinny and corkwing wrasse. On the right, a PIT tag and grip injector are used for tagging. Photo: Neginasadat Neghabat*

The total length of all species that were captured was measured. Every individual was scanned for the presence of a PIT-tag, and if a tag was present, the ID number was recorded. All wrasse individuals measuring 100mm and longer, which had not already been tagged, were tagged with a PIT tag.

Prior to tagging, the individual was anesthetized in 8 l of seawater with 50 mg 1-1 Tricaine methanesulfonate (MS222) (Figure 6) until it lost the ability to sustain equilibrium. The PIT-tag was then injected into the body cavity using a grip injector with a disinfected needle (Figure 5). In spawning season female wrasses were not tagged. After tagging, the individual was placed in a bucket with 10 L of fresh seawater to recover from the anesthesia and, subsequently gently released to the spot where it had been captured.

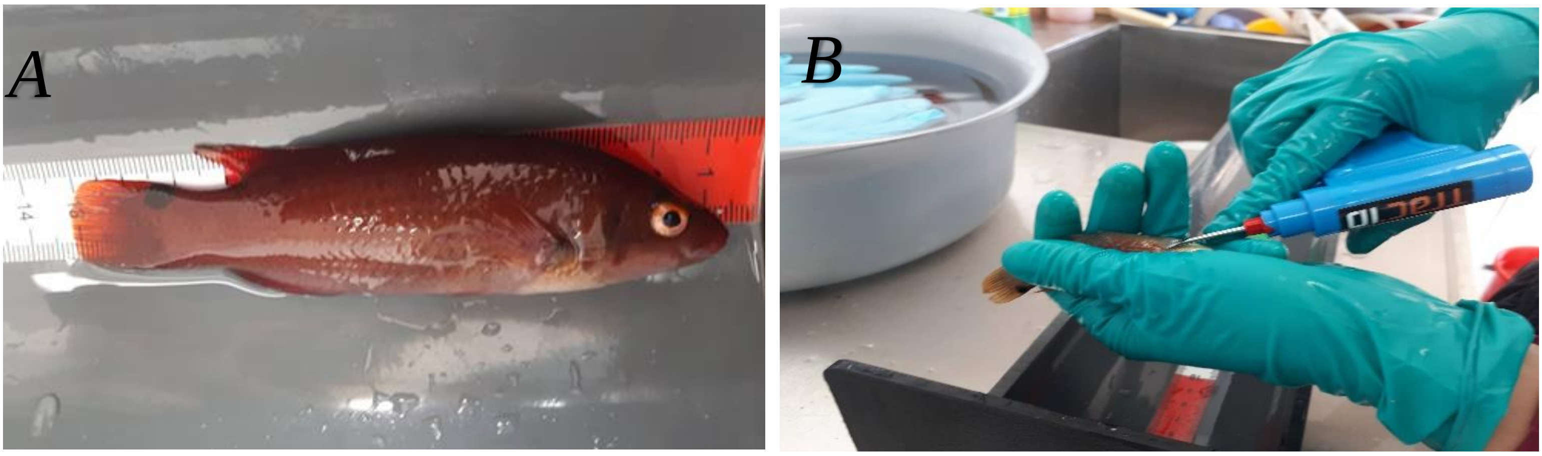


Figure 6: *A) Tricaine methanesulfonate (MS222) was used to anesthetize the individuals B) and targeted them with a PIT- tag injector and C) measured them with an edged measuring tool. Photo: Neginasadat Neghabat*

2.3 The four sessions

2.3.1 May tagging

From April 27th - May 29th, the spring catch and tagging were carried out at the pier. This period predates the spawning season, making it possible to tag both females and males without complications due to the presence of mature eggs, (which causes a swollen abdomen). During this session, one wrasse pot was set at each of the sex trap stations at a distance of, a 5-6 m, along the pier (Figure 9). This session is part of an annual routine, started in 2017, to monitor recaptures and tag new individuals at this location.

2.3.2 August tagging, pre-translocation

Fish were captured and tagged at the same six trap stations along the pier from August 10th - 14th, 2020, in order to tag more individuals. All the procedures and fish handling techniques used were the same as during the May session. All corkwing and goldsinny captured during this period, either newly or previously tagged, were transferred to nets along the pier pending the translocation experiment.

2.3.3 Translocation

The cumulated collection of 221 goldsinny wrasses and 116 corkwing wrasses were randomly divided into four groups according to sex and size categories [smaller or larger than the average length (110 and 120 mm for goldsinny and corkwing wrasse respectively)] as blocking factors to make the four groups as similar in sample size as possible.

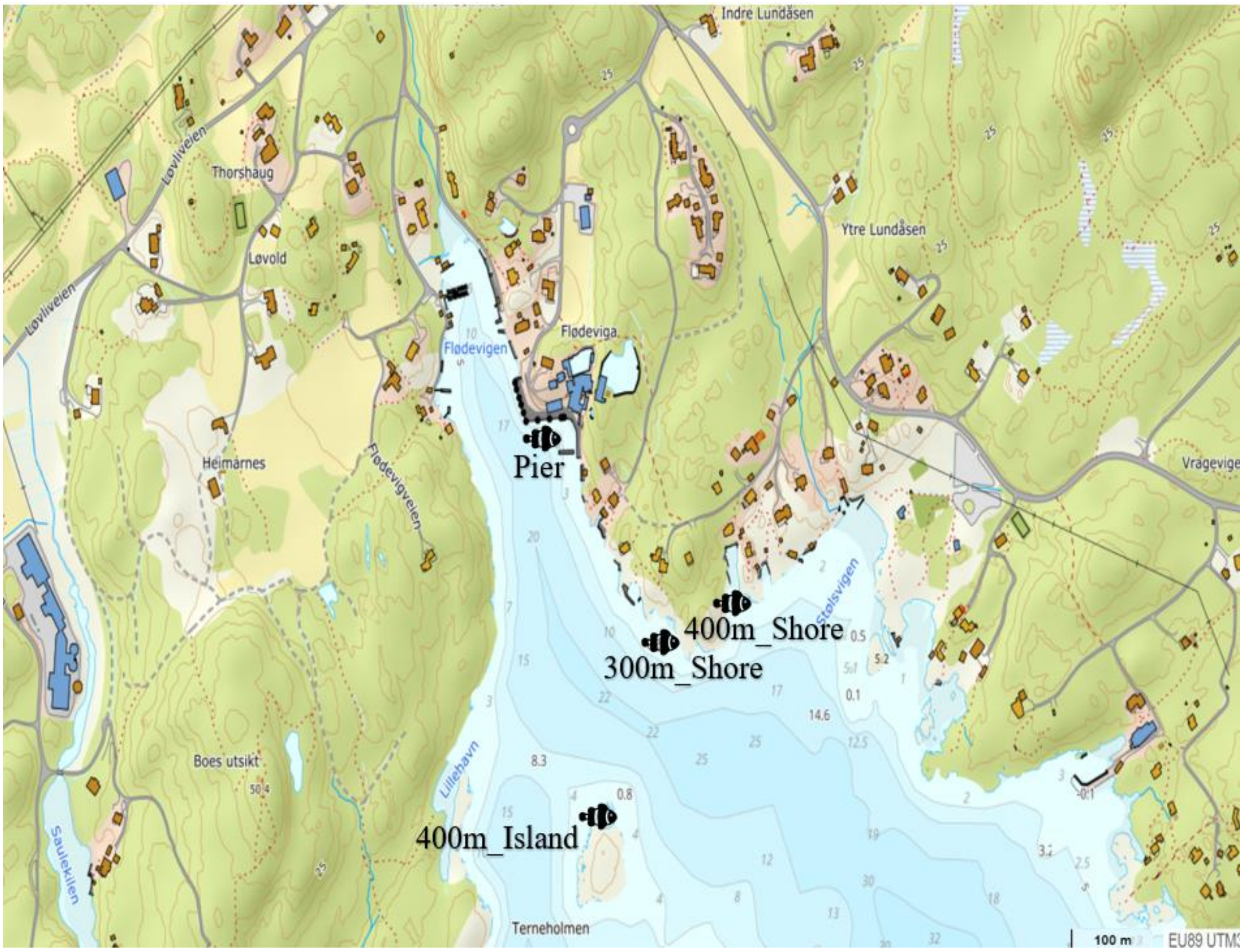


Figure 7: *The map shows the study area at Flødevigen and the four locations: Pier, 300m_Shore,400m_Shore, and 400m_Island where goldsinny and corkwing wrasses were translocated.*

Each group was randomly assigned to, and released at, one of four distinct site locations in the study area at 4 P.M. on August 14th, 2020. At the pier as a control group, 300m away from the pier along the shore, 400m away from the pier along the shore, and 400m away next to the island of Terneholmen (see Figure 7).

Considering the fact that Terneholmen is located 400 meters from the pier, the fish translocated here have the same net distance to swim as the fish translocated 400m along the shore; however, they must cross open waters to find their way back.

2.3.4 Recapture to detect homing

One hour after translocation eight circular PIT-tag reader antennas (RFID solution,Figure 8) were lowered under the water's surface to help detect the presence of any tagged individuals along the pier. Six of the antennas were placed close to each of the six standard stations along the pier, and the last two were placed 5-6m to the East and West of these respectively (Figure 9A). The PIT-tag system was prepared from August 14th - 24th.

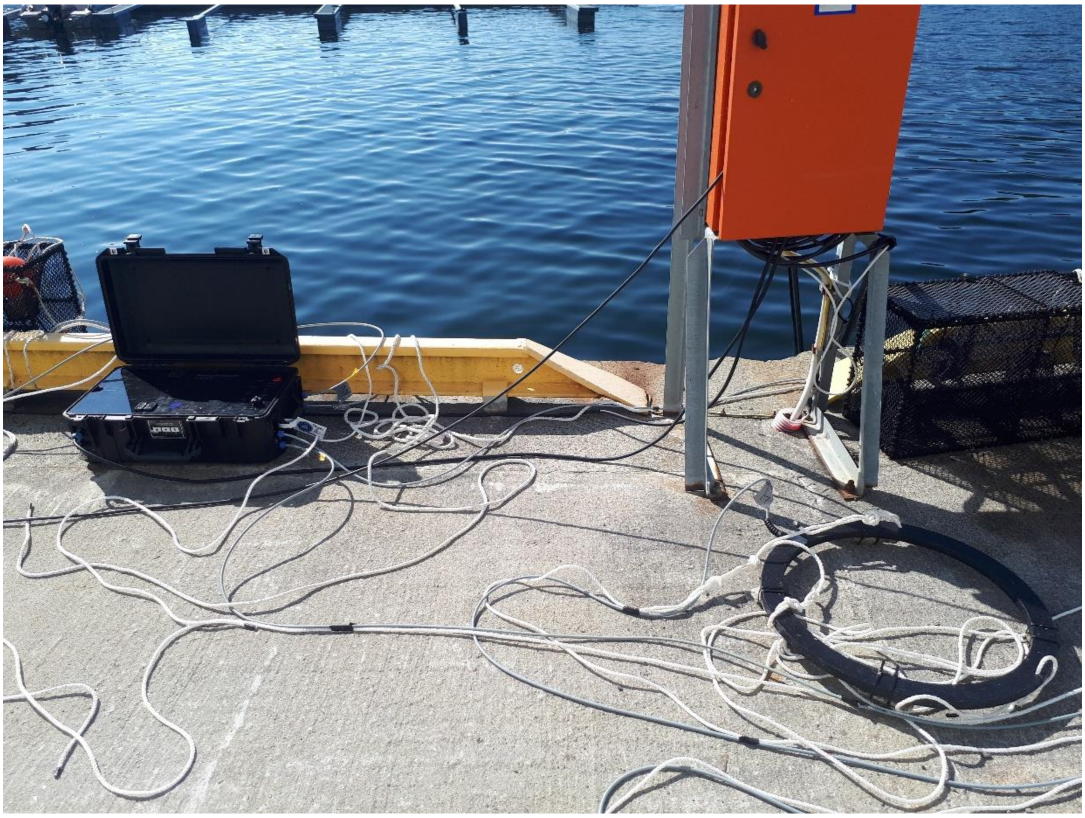


Figure 8: *PIT-tag antenna (circular shape on the right) and tag-reader (box to the left) that were used at the pier to detect PIT-tagged goldsinny and corkwings.*

One wrasse pot was set at the pier next to each of the eight antennas to increase the detection of tagged individuals at the pier (Figure 9A). In addition, 12 wrasse pots were set around the island of Terneholmen in an effort to recapture translocated individuals that could have ended up staying there after translocation (Figure 9B). For this purpose, wrasse pots were set on the 19th, 20th, 23rd, and 24th of August 2020.

On October 27th -28th, and November 3rd , 4th ,and 5th , pots were set at the same eight stations along the pier to detect late returners. During this latter part of the session, no pots were set at Terneholmen.

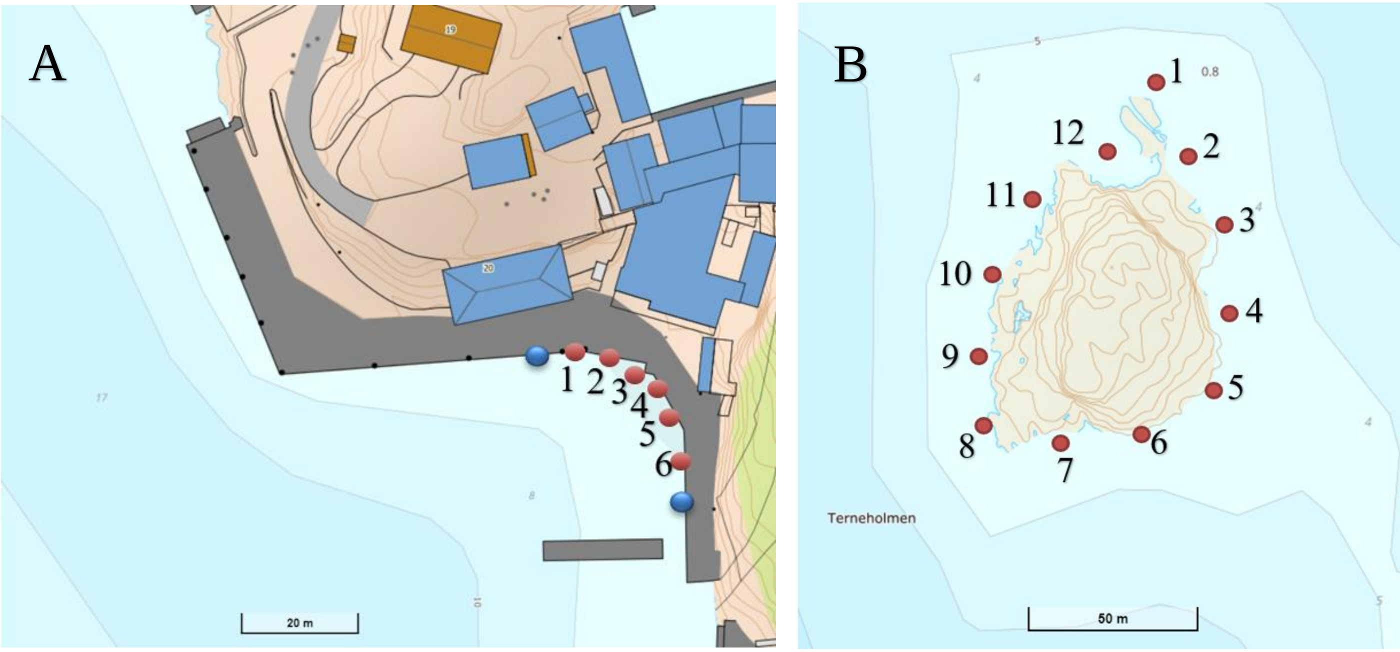


Figure 9: *A) Map with the position of the six normal stations for wrasse pots (red dots) and the two additional sites (blue dots) that were used to detect the presence of tagged wrasses. During the experiment, both pots and PIT-tag antennas were positioned on each of these stations. B) Map showing the island of Terneholmen in the southern part of Flødevigen, with the location of the 12 wrasse pots used to recapture translocated individuals.*

2.4 Data analysis

Statistical analysis was carried out using R version 4.0.3(R Core Team 2020), and R studio (version 1.3.1093). The ggplot2 package (Wickham 2016) and Excel version 2203 were used to create the graphs and visualize the data. The homing success of goldsinny and corkwing was evaluated using logistic regression. The homing of an individual was considered successful whether it was captured in one or several pots at the pier and if it was detected by one or several PIT-tag antennas at the pier after translocation. This does not represent an actual homing event for individuals in the control group (released at the pier), as this is more a matter of recapture, but I will use this term for all four groups for reason of simplicity.

For the logistic regression, the binomial response variable had two outcomes as they have homed without being detected by the antennas or being detected by them. The potential predictor variables included in the model selection were the translocation group (from here on called group), species (goldsinny or corkwing) and individual length in mm. First, I used the (group x species) model to evaluate the additive effect of species and group, as well as the interaction between these two predictors, and all simpler nested models, down to the null-model, were compared. The most parsimonious model from this model selection process was then used as the basis for the next model selection step.

Here, to investigate whether body size and sex affect homing success, separate models were run for each species. The effect of length, and its interaction with sex were included in this model, and all simpler nested models, down to the null-model, were then compared.

Return time, defined as the number of hours between translocation and the first detection by a PIT tag antenna at the pier, was evaluated using linear models. Due to the poor temporal resolution of capture data from pots, only data from PIT tag antennas were used to calculate return time; therefore, the dataset was smaller than that of homing access (as not all individuals captured in the pot were detected by any of the PIT tag antenna). The response variable was skewed towards low values, with a long right-side tail, and thus did not meet the assumption of normality. Therefore, the response variable was the square root transformed before analysis. The model selection procedure was similar to that of return probability, but because few corkwings managed to return (see results), the effect of individual covariates on return time was only evaluated for goldsinny wrasse.

The fit of all models was compared by using Akaike Information Criterion and corrected for small sample size(AICc) (Akaike, 1973). If the differences in AICc scores between two models were less than two units, the model with the fewest parameters is considered the most parsimonious model, and it is model (Burnham & Anderson, 2004) that has been used in this study.

3. Results

3.1. Overview:

All in all, 23 different species of fish were encountered during all sessions. Wrasse species constituted 88% of all fish captured, and 2842 goldsinnies, 462 corkwings, 90 rock cooks, and 36 ballan wrasses were captured (Figure 10).

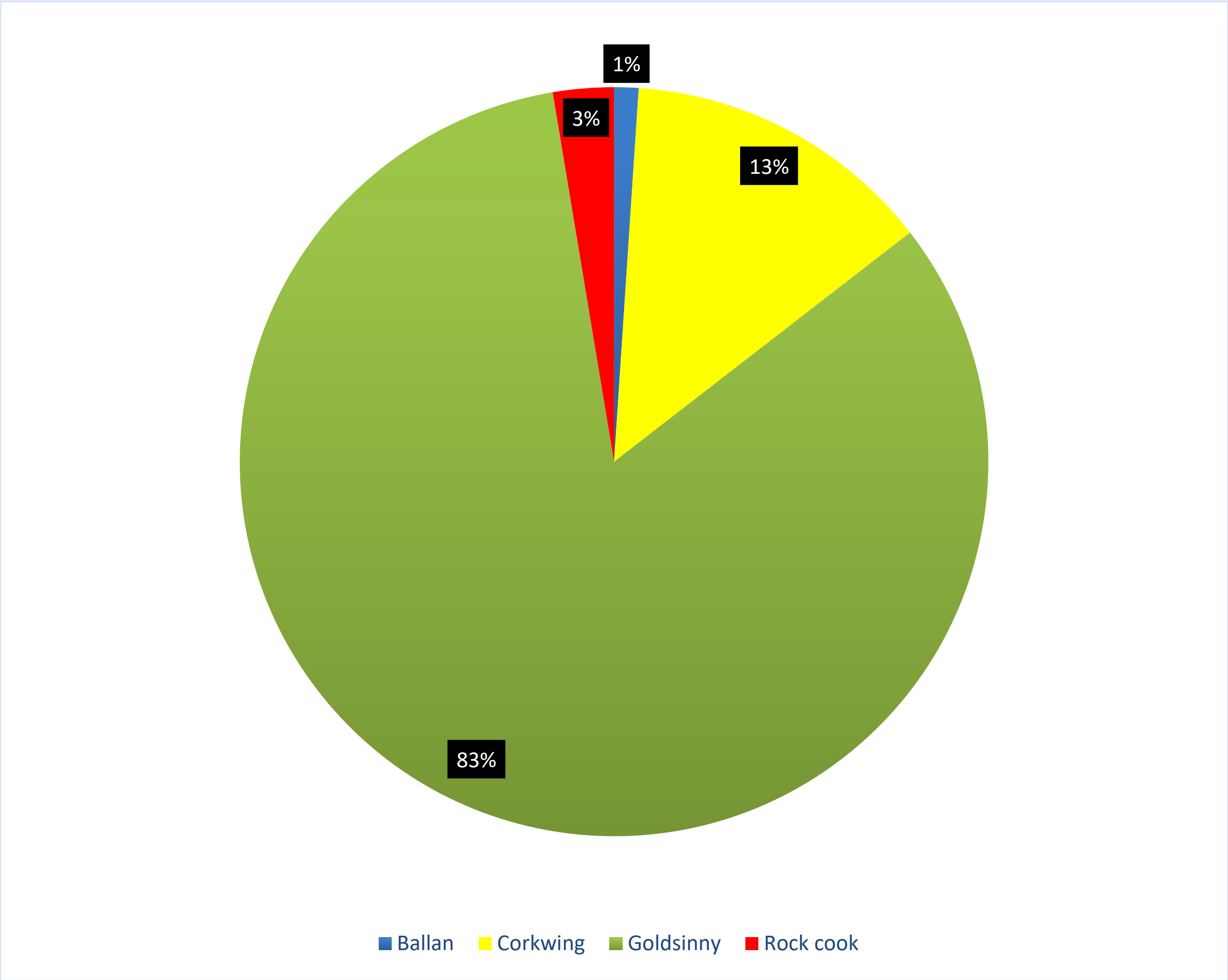


Figure 10: *The percentage of different wrasse species caught during the study in 2020.*

The length distribution, total number of individuals, and sex ratio of all four groups were comparable for each of the two species (Table 1).

Table 1: *The table shows sex, the number of maximum length, and a minimum length of all goldsinny and corkwing caught for translocation. Due to 100mm being the minimum length for PIT-tagging this was the minimum size of individuals in each group and for both species.*

		300m_Shore	400m_Shore	Control	400m_Island
Goldsinny	Females	30	28	31	26
	Males	27	26	26	27
	Length	(100 -141)	(100 - 132)	(100 - 138)	(100 - 127)
Corkwing	Females	16	16	19	16
	Males	11	13	13	12
	Length	(100 - 172)	(100 - 202)	(100 - 179)	(101 - 186)

The PIT tag antenna and captured results reveal that the majority of the goldsinny returned home in the control group, 300m shore, and 400m Island; however, only a few of them managed to come back from the 400m_Island. On the other hand, there are very few corkwings that managed to return home from control,300m_Shore and 400m_Island. Yet not a single corkwing returned from the island of Terneholmen (Figure 11). In addition, after translocation, there were a couple of corkwing wrasse captured on the island of Ternholmen.

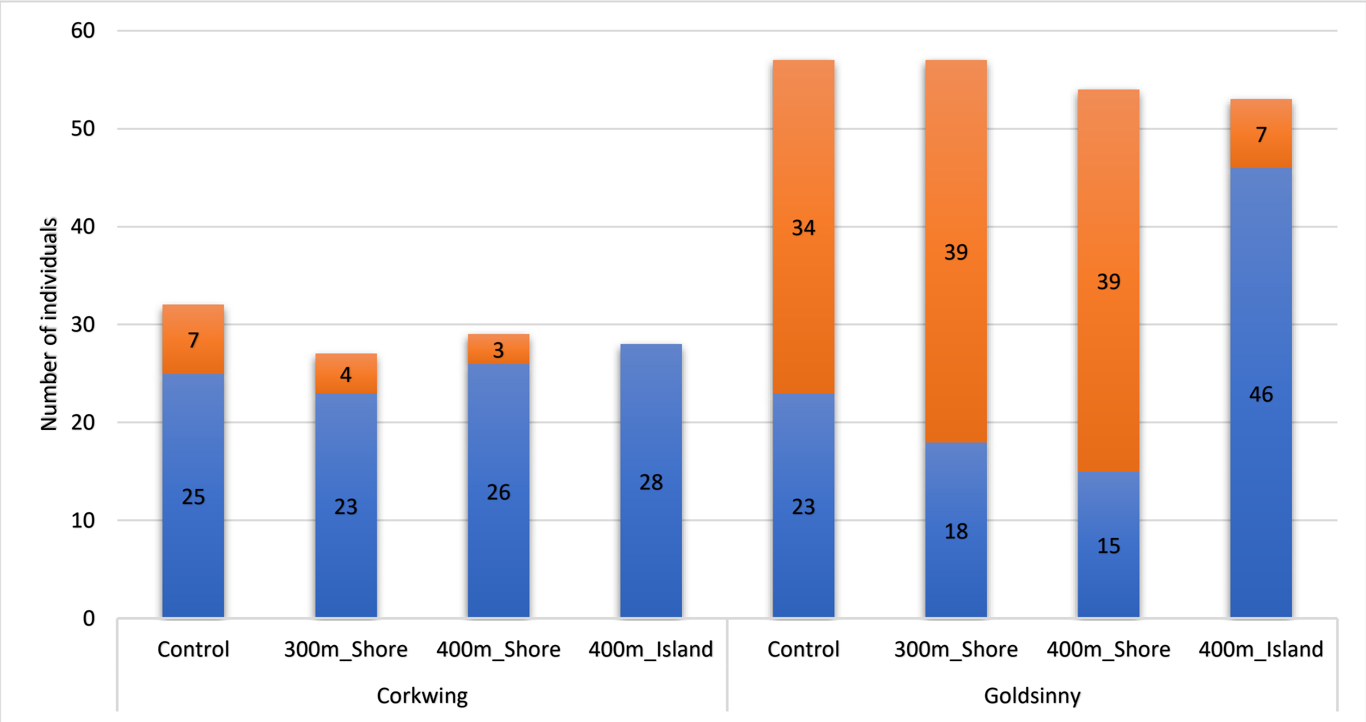


Figure 11: *Observed data of the number of goldsinny and corkwings that managed to return home (blue) and not return (orange) from the four groups. In the control group, "homing" in reality represents recapture at the pier as individuals in this group were not moved from the pier.*

3.2. Return Probability:

The model with an additive effect of group and species was the best among the models of the primary model selection. The group and species effects were present in the two best models, both of which were substantially better than the other models (ΔAIC ≥ 51.7). These two models together had a cumulative model weight of **(0.757+ 0.243=**)**1,** indicating a solid group and species effect. There is some evidence of a species-specific pattern in return probability, but these differences are only slight, given that the (group × species) model (Model 2) has a model weight that is roughly 1/3 of the best model (model 1) (**0.243 vs. 0.757**) (Table 2).

Table 2*: Model selection of logistic regression for the effects of biological features and translocation distances on the homing ability of goldsinny wrasse and corkwing wrasse. The table gives the summary of the model structure of interactions between groups and species with the numbers of parameters, AIC value, ΔAIC, and weight.*

Model Selection Table

	Intercept	group	species	group: species	Parameters	logLik	AICc	ΔAIC	weight
1	**0.58**	+	+		**5**	**-166.4**	**342.9**	**0.0**	**0.75**
2	**0.39**	+	+	+	**8**	**-164.4**	**345.2**	**2.3**	**0.24**
3	0.15		+		2	-195.3	394.5	51.7	0.00
4	-0.15	+			4	-201.0	410.1	67.2	0.00
5	-0.43				1	-226.0	454.1	112	0.00

The parameters of the best model show that overall, the corkwing wrasse has a significantly lower rate of homing success than the goldsinny wrasse (Table 3 and Figure 12). It also shows that the group effect is caused by a significantly lower homing success in the 400m_Island group compared to the control group. There are only slight, and significant, differences in homing success between the control group and the two groups translocated along the shore (Table 3 and Figure 12). Despite the substantial differences in homing success between the species, the overall within-group pattern was the same. The homing success of goldsinnies was around 0.65 for all, but the 400m_Island group was around 0.15.

For corkwing, the respective values were 0.15 and 0, meaning that none of the corkwings translocated to the island were confirmed as having returned, and only 7 out of 53 goldsinnies translocated there managed to return.

Table 3*: Summary of the model that performs best at explaining the variation in homing success between groups and species. The table shows the coefficients of the model, estimates, standard error, z-value, and p-value. Control and Goldsinny are reference levels.*

Coefficients	Estimate	Std. Error	z value	Pr (>|z|)
Intercept	0.58	0.25	2.28	0.02 *
300m – Shore	0.16	0.34	0.48	0.63
400m – Shore	0.21	0.35	0.60	0.54
400m – Island	-2.52	0.47	-5.32	<0.001***
species Corkwing	-2.40	0.33	-7.24	<0.001***

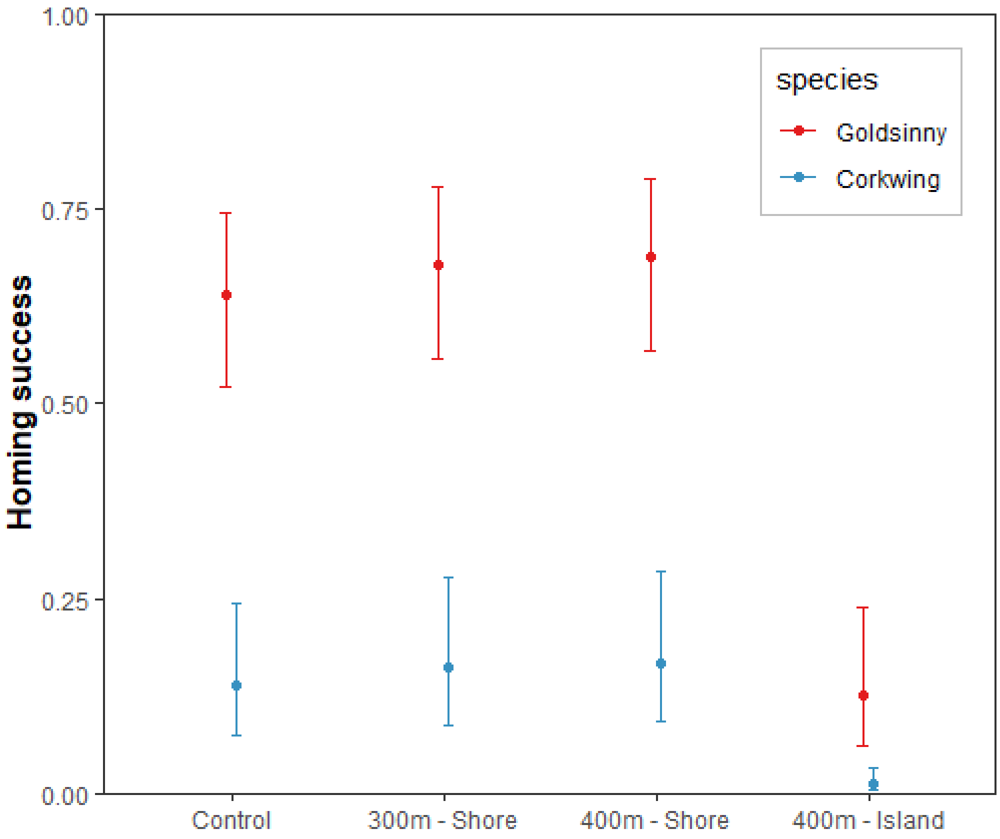


Figure10: *Predicted homing success of goldsinny wrasse and corkwing wrasse from the best model with an additive effect of group and species. Both species were good at homing success from the control group, 300m_shore, and 4oom_shore, and most goldsinnies managed to return home, and only 15% of corkwings manage to return. On the other hand, both species performed poorly when translocated to the island: moreover, corkwing wrasse perform much more poor than goldsinny wrasses altogether, with non-return from the island 400m away.*

3.2.1 Return probability model selection including the covariance of sex and length

Because there is no significant covariance sex and length impact on goldsinny wrasse, the model with this covariance demonstrates that it was not the best model, which includes neither sex nor length. With (**weight 0.52**) and (**AIC=261**), it only performed a group effect (Table 4).

The covariance length and sex model for corkwing wrasse demonstrated that this model with interactions is not the best model because while there is no significant length, there is a slight covariance sex effect with the (**weight 0.37**) and with (**AIC=83.1**). The most parsimonious model is with a group effect with (**weight 0.24**) and with (**AIC=83.9**) (Table 5).

Table 4: *Model selection of logistic regression for the effects of biological features and translocation distances on the homing ability of goldsinny wrasse. The table shows the covariance of sex and length in goldsinny wrasse alone and shows the groups, length, sex, and null model which compare these parameters together. There is a strong group additive group effect.*

Model	*selection*	*table*							
	Intercept	group	length	sex	Parameters	logLik	AICc	ΔAIC	weight
1	0.40	+			4	-126.6	261.3	0.00	0.52
2	1.48	+	-0.0099		5	-126.4	263.1	1.76	0.21
3	0.41	+		+	5	-126.6	263.4	2.08	0.19
4	1.54	+	-0.0102	+	6	-126.4	265.2	3.85	0.07
5	0.15				1	-152.5	307.1	45.7	0.00
6	0.72		-0.0052		2	-152.5	309	47.6	0.00
7	0.19			+	2	-152.5	309	47.7	0.00

Table 5*: Model selection of logistic regression for the effects of biological features and translocation distances on the homing success of corkwing wrasse. The table shows the covariance of sex and length in corkwing wrasse alone and shows the groups, length, sex, and null model which compare these parameters together. There is a strong group additive effect. There is also a slight group and sex effect as well because of the small sample size.*

Model selection table

	Intercept	group	length	sex	Parameters	logLik	AICc	ΔAIC	weight
1	-0.90	+		+	5	-36.269	83.1	0.00	0.37
2	-1.27	+			4	-37.782	83.9	0.84	0.24
3	-1.99	+	0.00919	+	6	-36.086	84.9	1.86	0.15
4	-2.06	+	0.00661		5	-37.675	85.9	2.81	0.09
5	-1.62			+	2	-41.204	86.5	3.43	0.07
6	-1.98				1	-42.722	87.5	4.40	0.04
7	-2.47		0.00718	+	3	-41.074	88.4	5.28	0.03
8	-2.42		0.00367		2	-42.684	89.5	6.39	0.01

3.3. Return Time:

The model with an additive effect selection is considered the additive effect of group and species and the interactions between them in both goldsinny wrasse and corkwing wrasses. For return time, only the group model is the best model, which is indicated by a substantial additive group effect in both species with the model (**weight 0.48**) and the lowest (**AIC=708.2**)(Table 6).

In return time, the minimum time that it takes for goldsinny wrasse and corkwing wrasse to return home was approximately 2 hours for both species; in addition, both of them translocated at the pier. The maximum time it takes for goldsinny wrasse to return home from the 300m-shore location is 196 hours. For corkwing wrasse, it takes 192 hours to go home from the 400m-shore location. These two types of fish return home after 8 days.

Table 6*: Summary of the model that performs best at explaining the variation in return time between groups. All estimates are square root transformed. The table shows the coefficients of the model, estimates, standard error, z-value, and p-value. Control are reference levels.*

Coefficient	Estimate	Std. Error	Z value	Pr (>|z|)
Intercept	6.79	0.53	12.83	<0.001
Group300m- Shore	0.59	0.74	0.80	0.43
group400m_ Shore	1.25	0.74	1.70	0.92
Group400m_ Island	4.09	1.38	2.96	0.003**

Table 7: *Model selection of logistic regression for the effects of return time and translocation distances on the homing ability of goldsinny wrasse and corkwing wrasse. The table summarizes the model structure of interactions between groups and species with the parameters of AIC value, ΔAIC, and weight.*

Model selection table

	Intercept	Group	Species	Group: Species	Parameters	logLik	AIC	ΔAIC	weight
1	6.78	+			5	-348.9	708.2	0.00	0.48
2	6.96	+	+	+	8	-346.2	709.6	1.39	0.24
3	6.79	+	+		6	-348.9	710.4	2.19	0.16
4	7.58				2	-353.8	711.7	3.42	0.09
5	7.63		+		3	-353.7	713.6	5.32	0.03

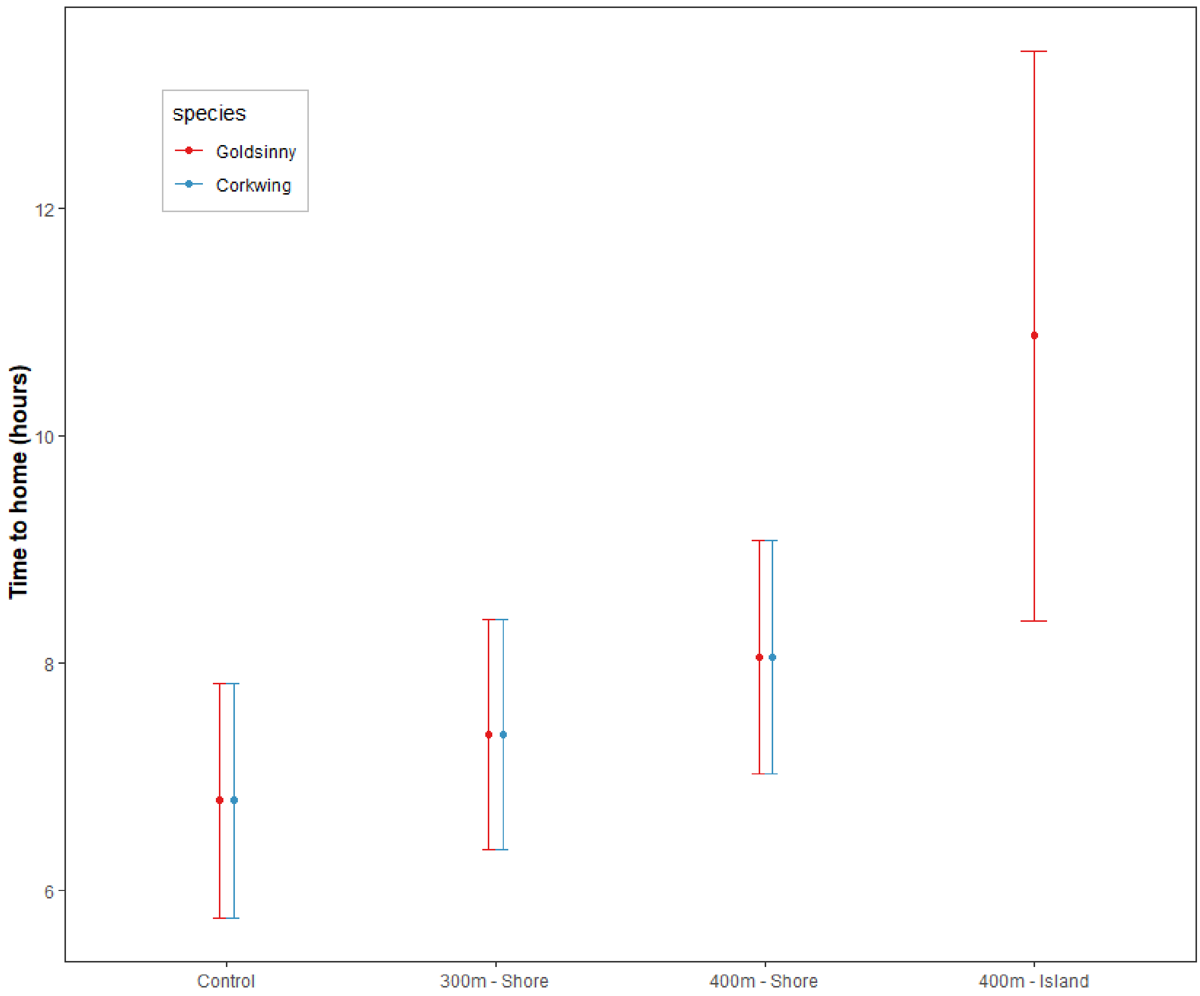


Figure11: *Predicted Time for goldsinny wrasse and corkwing wrasse to return home the chosen model, which was the best model and had the additive effect of group. The average return time for goldsinny and corkwing are around 7 hours for control group, 7.5 hours for 300m_shore, 8 hours for 400m_shore. According to these results, the return time is not significant between these groups (only between control and island). The average return time for goldsinny at 400m_island is around 11 hours.*

3.3.1 Return Time model selection including the covariates of sex and length

The covariates sex and length model for individual goldsinny wrasse shows it there was not the best model; it includes neither sex nor length because there are no significant covariance sex and lengths in either species. It performed the group effect alone with (**weight 0.34**) and with (**AIC=630**) (Table 7).

Table 8*: Model selection of logistic regression for the effects of return time and translocation distances on the homing ability of goldsinny wrasse. The table shows the covariance of sex and length; it also shows the groups, length, sex, and null model that compare these parameters together. There is a strong group additive group effect.*

	Intercept	*Group*	*Length*	*Sex*	*Parameters*	*logLik*	*AICc*	*ΔAIC*	*weight*
1	6.96	+			5	-310.0	630.6	0.00	0.34
2	3.75	+	0.0292		6	-309.7	632.1	1.54	0.16
3	7.63				2	-314.0	632.3	1.71	0.14
4	6.89	+		+	6	-309.9	632.7	2.11	0.12
5	3.80		0.03482		3	-313.6	633.5	2.91	0.08
6	7.47			+	3	-313.9	634.1	3.50	0.06
7	3.43	+	0.03117	+	7	-309.6	634.2	3.61	0.05
8	3.26		0.03791	+	4	-313.4	635.2	4.60	0.03

When the fish were released at 16:00 with a PIT tag antenna, the first fish that managed to return were the goldsinny wrasse, which took one hour to return home, and corkwing wrasse, which took two hours to return home. The last fish that returned home took 196 hours to return from the 300m_Shore; this species was the goldsinny wrasse. The last goldsinny that managed to return from the 400m_Island took 171 hours. The return times for these species are not the same, and goldsinny wrasse tend to return home faster than corkwings because of the variation in the sample size of both species.

5. Discussion

The purpose of this research was to investigate the homing ability of goldsinny wrasse and corkwing wrasse from various distances, as well as the time it takes them to return home. One of the project's initial goals was return probability, which was seeing if the corkwing wrasse and goldsinny wrasse would return home after being translocated at different distances. Following the translocation of goldsinny and corkwing wrasse, roughly 90% of all goldsinny wrasse that had been translocated 300m or 400m along the shore did return home. This number was similar to the recapture probability of the control group, but only around 10% of those translocated to an island 400m away did return. Among the corkwing wrasse, only 10% of those translocated along the shore did return, and no one returned after being translocated to the island. The second question in this investigation is how long corkwing and goldsinny wrasse take to return to their natural habitat. Corkwings and goldsinny wrasse have differing return times, with goldsinny wrasses returning faster than corkwings, and goldsinny wrasse taking a long time to return from the island 400 meters away from their home. The return time for corkwing wrasse is a little bit different from goldsinny wrasse, as it took the corkwing wrasse more time to return home from a 400m distance.

5.1 Return Probability:

The results of the return probability showed that when comparing control with the 300m and 400m distances, we can see that while 90% of goldsinny wrasse managed to return home, they did so from an island; at a 400m distance, only 10% of them returned home. However, Starbatty (2021) did not translocate goldsinny to the island, suggesting that these distances from 100m to 300m off the shore do not impact the goldsinny homing ability; consequently, they should be translocated at greater distances (Starbatty, 2021). In my study, although increasing the distances to 400m had no significant effect on return probability, by translocating goldsinny wrasse 400m and around the island which is 400m away from their habitat, only a very few goldsinny wrasses managed to return home. In my study, I also used corkwing wrasse and observed that from 300m and 400m distances, approximately 10% of corkwing wrasse returned home; the remainder of them not return. In addition, none returned from the island. This might be because they have a lower fidelity; that is, they do not have a fixed home range after the spawning period and thus do not have the same urge to return to where they were before. Maybe they were content to stay at the place where they had been moved. In fact, I did capture two of the translocated corkwings close to the island, but I did not catch any goldsinny while I did recapture, which shows a weakness of this theory. Goldsinny wrasse was also tagged before at the pier in a previous year before I did this research and goldsinny might know the way to return or might that the pier is their home and it's seemed that they linked to that place but for corkwing, wrasse might not the same. Maybe goldsinny has high fidelity according to the Starbatty (2021) results and maybe corkwing has low fidelity and is at the pier just for spawning time and going to other locations.

In addition, wrasse horizontal movement was examined by Aasen (2019), who found that the longest distances corkwing wrasse and goldsinny wrasse traveled were 592m and 385, respectively. He then examined the results with no translocation but more naturally occurring movement. According to Aasen's (2019) results, corkwing wrasse moved longer distances than goldsinny wrasse, which could show that corkwing wrasse are capable of moving further; however, they might not any interest in moving back. (Aasen, 2019). My findings revealed that the goldsinny wrasse's greatest distance travelled was 400 meters from the island. In my study, goldsinny wrasse translocated to 400m distance and they been forced to be at the distance; these movements did not naturally happen .The reason why the corkwing wrasse has a much lower return probability than the goldsinny wrasse might be that the goldsinny wrasse is more territorial than the corkwing wrasse and so prefers to return home.

The goldsinny wrasse and corkwing wrasse that did not return home from the island might be related to reasons like corkwing wrasse are more active than goldsinny wrasse; because of this, they might stay there or discover new locations. Also, in my research when I did the recapture at the island, I found two corkwing wrasse, which means that they might prefer to stay there instead of going back to their habitat. Another reason might be that they were eaten by cod or other predators. In my fieldwork, when I have recaptured goldsinny wrasse and corkwing wrasse, I have seen predation from cod in my pots.

In addition, I found that there is a lack of effect of sex and length for both species in return probability. This is not the expectation I had about the larger species being better swimmers than the smaller ones. The fact is that the capability of each species to home from distances varies a lot and does not necessarily correlate to size.

The sex differences in both goldsinny and corkwing wrasses had no effect on return probability, but Hilldén (1984) found a sex effect on homing ability, with four out of five goldsinny wrasse that return being female. He therefore suggests that this is because territorial male goldsinny had more trouble passing through other territories on their way back home than females, and they might even fight, other territorial males. Hilldén's (1984) study was based on very few goldsinny individuals, and the chance of returning more males or females was decreased. Also, in Starbatty's (2021) thesis, there was no sex influence on homing behavior in goldsinny wrasses. My findings are similar to hers: sex has no effect on return probability in corkwing wrasse.

5.2 Return Time:

My findings revealed that the return time for both goldsinny and corkwing wrasse is more or less the same over 300m and 400m distances. However, there is no return time for corkwing wrasse from the island since they did not return home from there. In addition, while there were a few corkwing wrasses that returned home, they did so return as quickly as the goldsinny wrasse despite the overall return rate, which was much lower. Out of 84 goldsinny wrasses and corkwing wrasses from 300m only 43 of them managed to return home, from 400m, 42 out of 83 and from island just 7 out of 81 individuals managed to return home. Most of the individuals managed to return in less than a day. These results are more or less the same as Starbatty’s (2021), and, according to her thesis, 26% of the goldsinny managed to return. However, in my study, it took 2 hours for both species to return home, which was the fastest time. Starbatty (2021) results showed that the fastest goldsinny takes less than 4 hours to return home. However, in other species like (*Epinephelus tauvina*), Arara and Rose (2004) found that there was no significant effect between return time and the different distances, which is opposite of my results (Kaunda-Arara & Rose, 2004). Also, another study that was done by Thyssen et al. (2014) on rock pool blenny (*Parablennius parvicornis*) suggests that if fish are translocated farther away, it takes more time for the fastest blenny to return home after 48 hours, and the slowest fish take 134 hours to return home from a 400m distance. The results that I recorded showed that the fastest fish that returned home took 2 hours to do so at the pier; The slowest fish took 196 hours to return home from a 300m distances.

Accordingly, I found that the goldsinny wrasse, which had been translocated along the shore, needed less time to return than if translocated the same distance to the isolated island. One possible explanation for this is that the depth and bottom structure of the bay discouraged individuals from moving straight across. As a result, they performed to follow the shallow areas to the northwest part of the island, continuing along the western shoreline back to the pier. Taking this longer route is expected to take more time, and this is follows Hilldén’s (1984) suggestion that the reason it takes time for goldsinny to return home might be the rocky barrier they need to go around instead of going straight. It can depend on water levels as well.

There were 133 goldsinny wrasse and corkwing wrasse that were recorded by PIT tag antennae: at the same time, there is no information about the other recaptured fish. The return time of the first goldsinny wrasse and corkwing wrasse that returned quickly was 2 hours from the pier, the same place where they had been captured. It might be that the PIT tag antenna did not record all the goldsinny and corkwing wrasse, and I do not know how quickly those individuals returned home. In addition, the overall recapture probability showed a successful homing ability; for example, in the control group, only 90% of the individual fishes were recorded. They might either have been going somewhere else, or this could have been due to a less than 100% probability.

In fact, in this study the results are similar to Starbatty's (2021); similar to her, I observed that goldsinny have a strong homing behaviour, and the majority of them can return home from longer distances and along the shore. Also, both results showed no significant effect of the sex and length variant on the return probability for goldsinny wrasse.

My results showed that when the depth of the bay increase, it is difficult for goldsinny wrasse and corkwing wrasse to return; this might be that having some kind of barrier makes them take a longer time to return. According to my results and Starbatty's (2021) research most of the goldsinny wrasse returned home because they might be more territorial, and maybe they prefer to return to their territory. Corkwings showed less fidelity, according to the low number of corkwing wrasse which captured from 300m and 400m distances and they did not return from island, or they might be stay there or discover new locations.

This research and these results can have an impact on Norwegian fisheries and their management. One area of future investigation could be to explore whether fishermen unintentionally move wrasse, which might in turn make it problematic for these fish to return to the ocean. According to my results, this is less of a problem than expected, at least for goldsinny. At the same time, it is less clear; however, what is less clear is what happens to the corkwings, since they did not return and so we do not know their fate. In my study, I released goldsinny along the shores to the 400m distances and the results showed that this distances around the shoreline are good and they can return home. In fisheries and management, fishermen can capture goldsinny and translocate them in 400m distance but there is point, that I am not sure what will be happen to goldsinny if they release in the open waters. Also, I translocated individuals and I observed that goldsinny wrasse can manage return home across the open water, but I didn't translocate them in open water. If we translocate them into the deep open water how they react. They might return home or not survive on that area. So, I am not sure if fishermen release individuals into the open waters.

Regarding the need for further study, I suggest translocating goldsinny wrasse and corkwing wrasse in open waters and see how they react. Also, in my study the number of corkwing individuals was limited for future research; therefore, it would be beneficial to increase the number of corkwing individuals. In addition, it would be interesting to translocate goldsinny wrasse and corkwing wrasse from the island to other locations to see how they react, are they would react and if, they would still return home or prefer to discover new areas.

6. Conclusion

In this study, I wanted to investigate the homing ability of goldsinny wrasse and corkwing wrasse. In this thesis goldsinny wrasse demonstrate strong homing ability up to 400m distances away from their home, but when they were translocated to an island 400m away from their home, they showed poor homing ability to return home. In addition, corkwing wrasse showed the moderate homing ability from the distances up to 400m, but they did not manage to return home from the island. Different distances along the shore did not seem affect return time except for individuals which translocated across the open waters. The return time has a lot variation depending on how quickly individuals return and goldsinny wrasse have higher homing ability than corkwing wrasse since there is no corkwing return from island and the results showed that both species equally quick when they return home. This research and these results about the homing ability of these fish provide valuable information regarding the wrasse species, which are widely used as cleaner fish in fisheries and management, if collected, measured and returned to other locations, these fish can have a significant impact on the population.

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