The movement of five wrasse species (Labridae) on the Norwegian west coast.

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Abstract

During the 1980`s it was discovered that fishes from the wrasse family (Labridae) along the Norwegian coast could be utilized as cleaner fish for controlling sea-lice infestations in commercial fish farming. Since this discovery, the demand for wild-caught wrasse has generated a large and profitable fishery. And subsequently, knowledge regarding the biology and ecology of temperate wrasses is needed to manage a sustainable fishery. In this thesis, I analyzed movements of the five wrasse species using mark-recapture data collected over five periods in 2017 and 2018 on three islands outside Huftarøy in Austevoll municipality in western Norway. A total of 8454 wrasses were tagged, and 839 were recaptured. The five species of wrasse found at the study location; Corkwing (*Crenilabrus melops*), goldsinny (*Ctenolabrus rupestris*), ballan wrasse (*Labrus bergylta*), rock cook (*Centrolabrus exoletus*) and cuckoo wrasse (*Labrus mixtus*). Horizontal movement made by individuals from these species was obtained by calculating the distance between observations. Life-history traits and environmental factors were then used in order to explain movement patterns. In this thesis, I found that the five species of wrasse moved locally with little horizontal movement. This was reinforced by the lack of observations of movement between the three islands. Corkwing wrasse was found to have moved longer distances with larger body size, and the island and habitat where captured had an effect on the distance traveled. Goldsinny wrasse was found to move shorter distances than corkwing, and the island where captured influenced horizontal movement. Factors influencing the recapture probability was found to mirror factors influencing movement, and the time of year influenced the probability of being recaptured.

Local island populations of territorial fishes such as the wrasses in this study are particularly vulnerable to overexploitation and would likely struggle to recover. The movement patterns observed for corkwing make this species especially susceptible to sex-selective harvesting, which can have a negative impact on population productivity. The way fishes move is directly linked with the probability of being harvested. In order to protect small local populations of temperate wrasses, further research on wrasse movement should be carried out with different techniques such as acoustic or radio telemetry in order to get a more detailed understanding of the movement patterns of the five species of wrasse found along the Norwegian coast.

Contents

1 Introduction

Movement plays an essential role throughout a fish's life. It can be made vertically or horizontally in the three-dimensional space provided by the sea. It is associated with feeding, spawning, refuge from predators, social behavior, and habitat selection. The activities that determine whether a fish thrives or dies. Fishes can undertake long, dangerous journeys like the Atlantic salmon (*Salmo salar*) traversing vast stretches of ocean to reach the stream from which they emerged (Hendry et al. 2003). Or they can be stationary, living within and around one small sea anemone for the entirety of their life like the clownfish (Dunn 1981). And everything in between. Little, however, is known of the movements and what role they play for the wrasses found along the Norwegian coast.

There are five common species of wrasse in Norway; Corkwing wrasse (*Crenilabrus melops*), goldsinny (*Ctenolabrus rupestris*), ballan wrasse (*Labrus bergylta*), rock cook (*Centrolabrus exoletus*), and cuckoo wrasse (*Labrus mixtus*) (Costello 1991). They are among the most numerous fish species found on shallow rocky reefs and coastlines in northern Europe (K. T. Halvorsen, Larsen, et al. 2017). Scale-rayed wrasse (*Acantholabrus palloni*) also appear along the coast and might be more numerous than previously assumed, though it usually inhabits deeper waters throughout its life and is proven difficult to capture with conventional methods (Costello 1991; Moen 2014).

These species belong to the wrasse family (Osteichthyes: Perciformes: Labridae) the currently third most speciose marine fish family with around 550 fish species in 70 genera (Paolo Parenti and Randall 2018). This diverse and fascinating group of fishes, often recognized by their thick lips and bright, and often stunning coloration (Wheeler 1969) are found in tropical, subtropical and temperate seas, most commonly in shallow water habitats such as coral reefs, rocky reefs, sand, grass, and algae (Westneat and Alfaro 2005). Most species are relatively small with a body length less then 20cm, but species size can range from 5cm to 230cm (P Parenti and Randall 2000). The family also displays considerable morphological variation related to color and body shape, with species featuring bulbous heads such as the Asian sheepshead wrasse (*Semicossyphus reticulatus)* or extrudable trumpet-shaped mouths as in the Sling-jaw wrasse (*Epibulus insidiator*).

The Norwegian wrasses are no exception. The five species show sexual dimorphism where the larger male is often brightly colored with intricate markings (Wheeler 1969). They are territorial and display complex social behavior such as courtship and nest building, where the larger dominant male provides parental care during the spawning season (Costello 1991). One may also encounter type-2 males or “sneaker males” that disguise themselves as females in order to steal fertilizations from the territory males (Sayer, Treasurer, and Costello 1996; K. T. Halvorsen, Larsen, et al. 2017; K. T. Halvorsen, Sørdalen, et al. 2017; Uglem, Rosenqvist, and Wasslavik 2000). There is also the protogynous hermaphrodites ballan and cuckoo wrasse that can maintain large harems of females, and change sex when they have reached a certain size (Muncaster, Norberg, and Andersson 2013; Darwall et al. 1992; Dipper and Pullin 1979).

The territorial behavior found in temperate wrasses is likely to influence their movement patterns and home range. The home range is the area utilized for activities such as feeding or resting, during part or all of its lifetime (Grüss et al. 2011). The extent of the territoriality and if members of the species are confined by it, and how and if environmental factors affect the movement of these species, is not extensively researched. The consensus is that the temperate wrasses are somewhat stationary with small home ranges along the Norwegian coast (Espeland et al. 2010). Still, some studies have shed light on the subject.

The temperate wrasses are diurnal and mainly associated with the benthic (Costello 1991; Hilldén 1984). Activity is limited to daylight and wrasses sleeping in a crevice or nest during the night have been observed on several occasions (Collins, Jensen, and Mallinson 1996; Hilldén 1984; Costello 1991). Along the Swedish coast, it was found that the size of the male goldsinny territory ranged from 1.4 - 2 m^2 with a shelter as the center of activity. Movement behavior such as foraging and patrolling was restricted to this territory or in close vicinity, and females mainly stayed within its limits (Hilldén 1981). Costello (1995) observed that male corkwing territories could exceed 15 m^2, and a mark-recapture study carried out in the Storebø bay in western Norway suggested that corkwing wrasse appears to have limited horizontal movements, and high site fidelity (K. T. Halvorsen, Sørdalen, et al. 2017). Ballan wrasse has been found to have high site fidelity and a small home range (Villegas-Ríos, Alós, et al. 2013). Shoaling behavior has also been reported for rock cook (Hilldén 1984; Thangstad 1999; Costello, Darwall, and Lysaght 1995).

Prior to 1987, temperate Labrids were not considered a commercially valuable resource due to their relatively small size, and little was known of their ecology (Wheeler 1969; Darwall et al. 1992). This however changed when it was discovered that wrasses could be utilized as cleaner-fish in order to restrict sea-lice infestations by the copepod ectoparasite *Lepeophtheirus salmonis* in commercial farming of Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) (Bjordal 1988, 1991). This symbiotic relationship between an individual and other, often larger fish, eating and relieving their skin of parasites, had been known in tropical reef Labrids for some time. Cleaning behavior was first reported in temperate wrasse by Potts (1973) where *Ctenolabrus rupestris* and *Crenilabrus melops* were observed cleaning other fish in display tanks, along with field observations of *Centrolabrus exoletus* cleaning *Labrus bergylta*. Hilldén (1983) later recognized this behavior by *Ctenolabrus rupestris* along the coast in Sweden. Since the first trials where wrasse was introduced to sea cages with farmed salmon (Bjordal 1991, 1988), the practice of delousing in this manner as a supplement to other treatments with chemicals has been instrumental in aquaculture to this day (Norwegian Directorate of fisheries[1]).

Demand for wild-caught wrasse in Norwegian aquaculture has increased significantly since its introduction, thus generating a large and profitable fishery. Especially after 2007-2008, when the sea lice evolved resistance to most of the available pesticides (Skiftesvik et al. 2014). The fishing usually takes place from mid-July until the end of October in southern Norway and from the end of July until the end of October in northern Norway (Norwegian Directorate of fisheries[2]). This period can coincide with the wrasse spawning season but may allow some wrasse to spawn before being harvested (K. T. Halvorsen et al. 2016). The catch is mainly composed of goldsinny and corkwing wrasse (Appendix; table 1). The fishery had its peak year in 2017 with over 27 million landings, although a landing cap of 18 million was set in 2016 divided over three regions (Norwegian Directorate of Fisheries[3]). This intensive fishery raises concerns about its long-term sustainability, and studies have shown that wrasse fisheries have an impact on the target populations and population dynamics (K. T. Halvorsen et al. 2016; K. T. Halvorsen, Sørdalen, et al. 2017; K. Halvorsen 2016). Recent studies have also found that there are natural habitat discontinuities along the Norwegian coast that prevent

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[1] https://www.fiskeridir.no/Yrkesfiske/Tema/Leppefisk

[2] https://www.fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer/J-meldinger/Gjeldende-J-meldinger/J-128-2019

[3] https://www.fiskeridir.no/Yrkesfiske/Regelverk-og-reguleringer/J-meldinger/Gjeldende-J-meldinger/J-128-2019

dispersal; this has caused a genetic break between western and southern populations of corkwing wrasse (Gonzalez, Knutsen, and Jorde 2016). The translocation of wrasse species over large geographical distances for cleaning purposes in aquaculture can therefore pose problems. Wrasses have been found to successfully escape from salmon farms and hybridize with local populations (Faust et al. 2018). And the hybridization of wrasses translocated from two genetically distinct populations is likely to alter the genetic composition of the local populations (Blanco Gonzalez et al. 2019). Overall there are many concerns regarding the wrasse fishery, and consequently, the need for knowledge concerning the north European Labrids biology, ecology, and life, is necessary for a sustainable fishery.

This thesis´ primary objective is to examine the movements of the five different species of wrasse found at three separate islands in western Norway. By performing a mark-recapture over the course of a year, I was able to obtain measurements of the distance traveled by individual wrasse, and by filming the seafloor, I was able to categorize habitats. I tested whether life-history traits and environmental factors influence the capture probability and movement patterns observed. I also examined differences in movement patterns between the different species of wrasse and Islands.

In summary, this study aims to

- Examine and compare the different movement patterns observed by the different species of wrasse at the study locations.
- Describe intraspecific movement with respect to life-history traits and environmental factors.
- Consider the implications the observed movement patterns might have in light of an intensive wrasse fishery.

2 Material and Methods

2.1 Study species

The five species of wrasse used for this study were corkwing wrasse, goldsinny wrasse, ballan wrasse, rock cook, and cuckoo wrasse (figure 1, table 1).

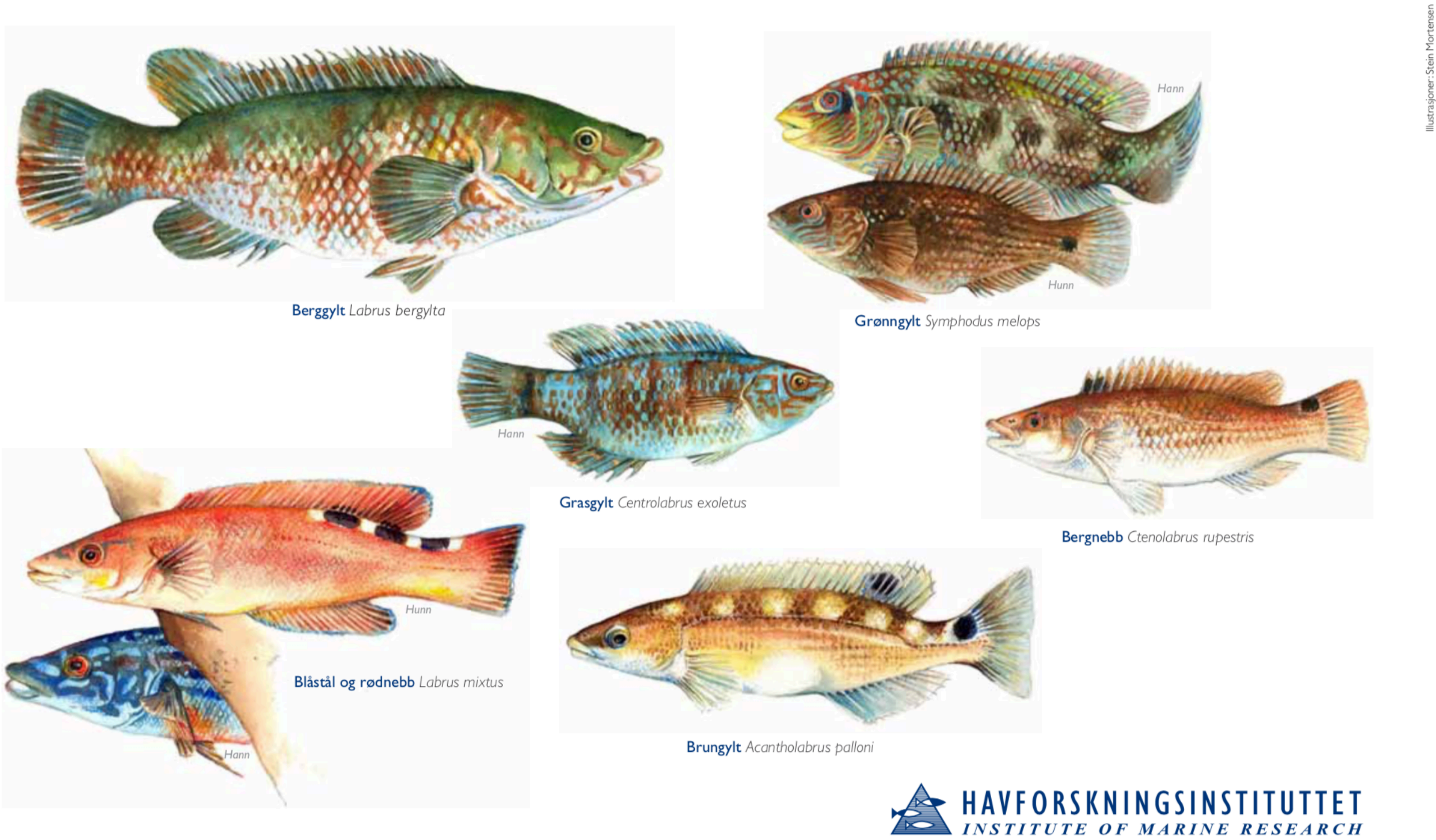


Figure 1: Illustration of the wrasse species found in Norway, courtesy of the Institute of marine research in Norway. Upper left: Ballan wrasse, upper right in front: Corkwing wrasse female, upper right behind: Corkwing wrasse male, center: Rock cook, center right: Goldsinny wrasse, bottom left in front: Cuckoo wrasse female, bottom left behind: Cuckoo wrasse male, bottom right: Scale-rayed wrasse.

Table 1: Life history table of North European wrasse (*Spawning season is temperature dependent and may vary). (Deady and Fives 1995b; Wheeler 1969; Costello 1991; Sayer, Gibson, and Atkinson 1995, 1996a; Deady and Fives 1995a; Darwall et al. 1992; Sayer, Gibson, and Atkinson 1996b; Dipper, Bridges, and Menz 1977; Hilldén 1984; Moen 2014; Skiftesvik et al. 2015).

Species	Max-size (mm)	Age at maturity (years)	Max-age (years)	Sex system	Sex change	Eggs	Spawning season *	Diet
Ballan wrasse	600 (3.5kg)	♀ 2-8 ♂ 6-9	29	Protogynous hermaphrodite (monandric)	Yes	Benthic	Early spring (May-July)	Molluscs and crustaceans
Cuckoo wrasse	350 (1kg)	♀ 2 ♂ 6-9	17	Protogynous hermaphrodite (diandric)	Yes	Benthic	Early spring (May-July)	Crustaceans
Corkwing wrasse	250	1-3	9	Gonochoristic	No (primary males)	Benthic	Early spring (May-July)	Molluscs and crustaceans
Goldsinny wrasse	205	1-2	20	Gonochoristic	No	Pelagic	Early spring (May-July)	Molluscs, crustaceans and polychaetes
Rock cook wrasse	190	1-2	9	Gonochoristic	No	Benthic	Early spring (May-July)	-

Corkwing wrasse:

Corkwing wrasse is a relatively small wrasse that can be distinguished by three anal spines, large scales, and a rather small and pointed head (Wheeler 1969). It also possesses a black spot on the caudal peduncle, on or slightly below the lateral line, and a comma-shaped spot behind the eye (Sayer, Treasurer, and Costello 1996; Wheeler 1969). There is evident sexual dimorphism (Uglem, Rosenqvist, and Wasslavik 2000; G. W. Potts 1974; K. T. Halvorsen et al. 2016). The secondary males or “nesting males” are often mottled green/brown with vivid blue and orange striped patterns on the head and operculum, whereas the coloring of females and juveniles are dull green-brown. Mature females also have a conspicuous dark blue urogenital papilla (Sayer, Treasurer, and Costello 1996; Wheeler 1969; Costello 1991). There are also functional primary-males or “sneaker males” that have female appearance, including the abdominal swelling during the spawning season, making visual sexual differentiation difficult outside the spawning season when individuals can be checked for sexual products (roe/milt) (Sayer, Treasurer, and Costello 1996; K. T. Halvorsen, Larsen, et al. 2017; K. T.

Halvorsen, Sørdalen, et al. 2017; Uglem, Rosenqvist, and Wasslavik 2000). Nesting males grow faster and become larger than females and sneaker males but tend to mature a year later(Uglem, Rosenqvist, and Wasslavik 2000). During the spawning season, the nesting males defend a territory where they create and maintain a nest using algae and seaweed and provide parental care by oxygenating eggs laid by multiple females (Geoffrey W. Potts 1985), and sneaker males will attempt to fertilize the eggs posing as females (K. T. Halvorsen, Sørdalen, et al. 2017). Corkwing wrasse is distributed in the eastern Atlantic from Morocco to the north-western coast of Norway and is typically found in areas with algal-cover on rocky shores in depths less than 5 meters although they can occur in depths of 15-18 meters (Sayer, Treasurer, and Costello 1996; Costello 1991).

Goldsinny wrasse:

Considered the smallest of the north European wrasses, goldsinny is distinguished by its brown/orange-red coloration with two recognizable dark spots. One is located on the anterior of the dorsal fin between the first four or five spines; the second spot is on the posterior at the upper part of the caudal peduncle (Wheeler 1969; Sayer, Treasurer, and Costello 1996). The males grow faster than females, but there is little sexual dimorphism (Olsen et al. 2019). Males can be visually distinguished from females by having orange or red spots on the lower part of their abdomen and smaller gonads, particularly during the spawning season(Hilldén 1981). Goldsinny wrasse is common inshore along the eastern Atlantic coasts from Morocco to Norway, and also recorded throughout the Mediterranean, the English Channel, the North Sea and the Baltic(Wheeler 1969; Sayer, Treasurer, and Costello 1996). A typical goldsinny habitat is often found on rocky shores, in the association with a shelter hole (Hilldén 1981; Sayer, Treasurer, and Costello 1996), and they can venture down to a depth of 44 meters (Sayer, Gibson, and Atkinson 1993).

Ballan wrasse:

Ballan wrasse is a heavy-bodied fish and the largest wrasse in northern Europe (Wheeler 1969). The coloration of the ballan wrasse is highly variable, but it is not associated with the sex of the individuals, unlike with other protogynous species like the cuckoo wrasse (Villegas-Ríos, Alonso-Fernández, Domínguez-Petit, et al. 2013; Costello 1991; Villegas-Ríos, Alonso-Fernández, Fabeiro, et al. 2013). The ballan wrasse is a monandric protogynous hermaphrodite where juveniles first mature as a female when approximately 16-18 cm, and then change sex to male when reaching 34-41 cm, this change can also depend on sex ratio and other external cues (Muncaster, Norberg, and Andersson 2013; Darwall et al. 1992). Two main color patterns occur and coexist in sympatry; plain which is uniform although the color scheme may vary (green, brown or red), and spotted, where there are high color variability and the presence of white spots (Costello 1991; Villegas-Ríos, Alonso-Fernández, Fabeiro, et al. 2013). The ballan wrasse is recorded along the eastern Atlantic coasts from Morocco to Norway. It is often found in rocky areas also inhabited by goldsinny wrasse and corkwing wrasse, and have been found below 30 meters (Sayer, Treasurer, and Costello 1996).

Rock cook:

The rock cook is recognized by its small mouth, a relatively long anal fin with five strong anal spines, and black bands at the base of the caudal fin and dorsal fin. (Wheeler 1969; Sayer, Treasurer, and Costello 1996). Rock cooks are a dull brown to green-blue, the females are mainly brown, and the males have iridescent blue-purple stripes (Hilldén 1984; Sayer, Treasurer, and Costello 1996; Costello 1991). It is absent from the Mediterranean but found from the coast of Portugal to western Norway, with reports of occurrences in Greenland (Sayer, Treasurer, and Costello 1996; Costello 1991). Rock cook has been observed at depths below 40 meters, but it usually populates eelgrass or rocky shores (Costello 1991; Wheeler 1969; Sayer, Treasurer, and Costello 1996; Espeland et al. 2010).

Cuckoo wrasse:

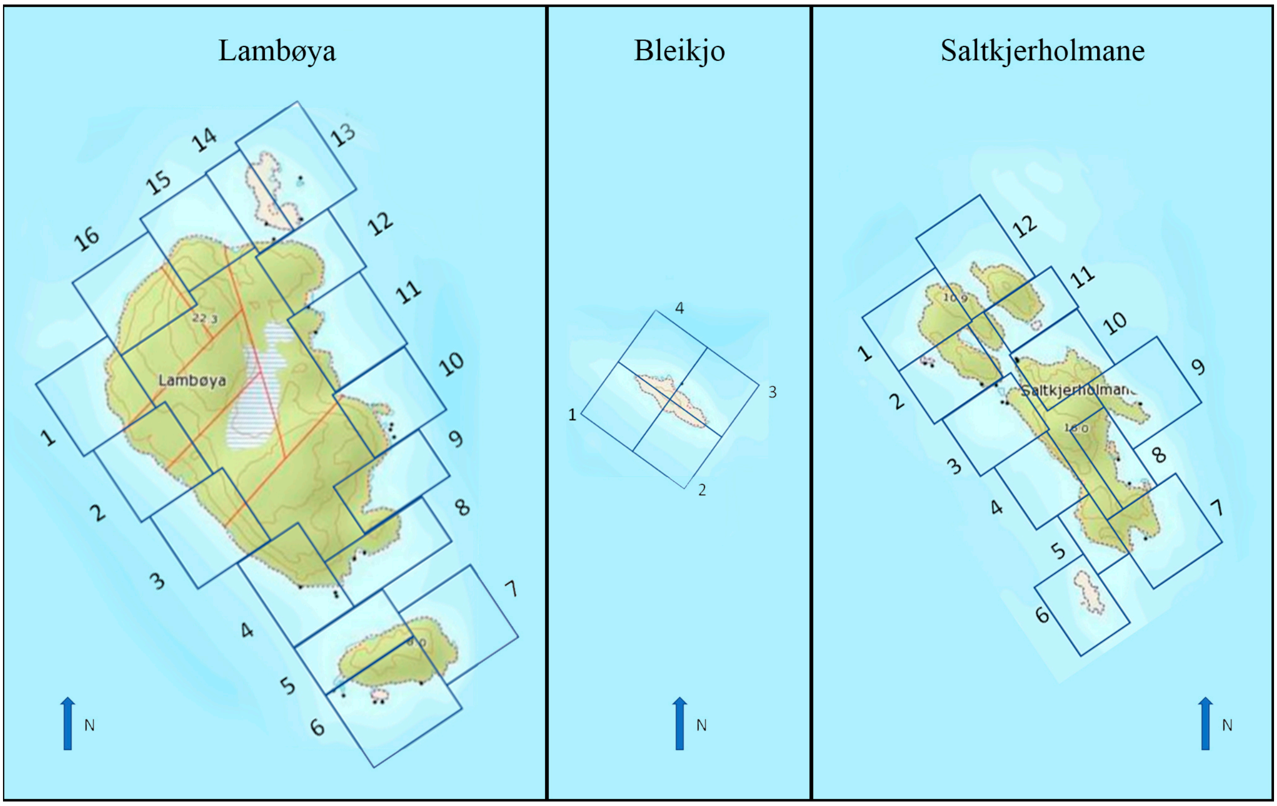
Cuckoo wrasses are unmistakable among the European wrasse due to its relatively slender shape, elongated head, big mouth, and coloration (Wheeler 1969). Cuckoo wrasse is a diandric protogynous hermaphrodite (Dipper and Pullin 1979) where primary males and females are red-brown to orange, with conspicuous dark and white marks along the back and dorsal edge of the caudal peduncle (Lythgoe and Lythgoe 1992; Sayer, Treasurer, and Costello 1996). Secondary males are brilliant orange with iridescent blue stripes and patches, particularly along the anterior portion of the body and head (Sayer, Treasurer, and Costello 1996; Espeland et al. 2010). Cuckoo wrasse is found along the coasts of the eastern Atlantic from Senegal to Norway, including Madeira, the Azores and throughout the Mediterranean (Wheeler 1969; Sayer, Treasurer, and Costello 1996; Lythgoe and Lythgoe 1992). Cuckoo wrasse is found to have a large depth range that can reach 200 meters, though it is usually found along rocky shores (Costello 1991).

2.2 Study location

The study took place along the shoreline of three islands outside Huftarøy in Austevoll municipality in western Norway. The three islands; Lambøya (including Lambøyskjeret), Bleikjo and Saltkjerholmane (figure 2) have been protected from commercial wrasse fishing since 2017. The three islands vary in topography and size, Lambøya being the largest and Bleikjo the smallest. The southeastern side of the islands facing Huftarøy is more sheltered than the side exposed to Bjørnafjorden to the east.

Figure 2: Map depicting the marine protected area and three islands used for this study. The northernmost island within the MPA is Lambøya. Bleikjo is in the middle, and Saltkjerholmane is the southernmost island. Edges of the marine protected area are noted with coordinates

The three islands were divided into multiple zones. Lambøya was divided into 16 zones (1-16), Bleikjo into 4 zones (1-4), and Saltkjerholmane into 12 zones (1-12) (figure 3). The average length of the shoreline (low tide) at each zone is 141.8 meters at Lambøya, 79.8 at Bleikjo and 141.3 at Saltkjerholmane.



Lambøya

Bleikjo

Saltkjerholmane

Figure 3: Map with the division of zones for each island. Left: Lambøya, middle: Bleikjo, right: Saltkjerholmane.

2.2.1 Habitat classification

During September 2018, two days were used to classify habitat around the islands. This was accomplished by filming the seafloor with a GoPro Hero 6 black camera attached to a drop camera (UVS 5080) that gave a live feed on a screen. This allowed regulating the depth of the camera, giving a clear picture of the areas of interest. Filming was done along transects in each of the zones, from approximately 20-30 meters ashore inwards toward land, maintaining a steady pace. There were 3-5 transects in each zone, depending on the topography and size of the zone. The footage from each transect was further divided into five pictures taken at even intervals. The pictures were then formed into a collage and analyzed to determine the substrate and dominating algae in each zone (figure 4).

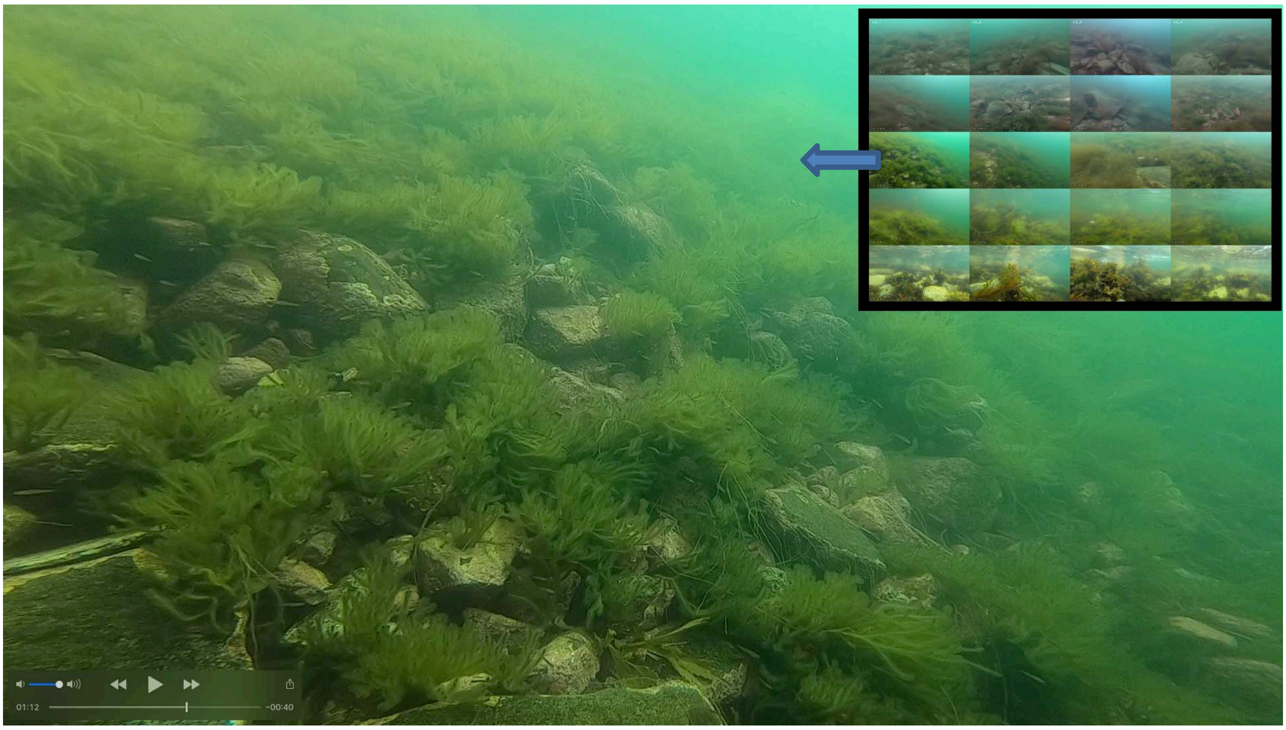


Figure 4: Picture of the seafloor at a determined interval (3) along transect (1) in zone 3 at Lambøya. In the top right corner is the collage made for the entire zone. Zone 3 was categorized as a Type B habitat, Thread algae dominated habitat and sheltered habitat.

In order to distinguish the habitats from each other, I focused on the differences in substrate, algae diversity, dominant species of algae, algae coverage, and biomass. Three habitat categories were created:

Habitat1: Habitat1 divided the habitat into four groups:

- Type A: Was dominated by kelp species. The most abundant kelp species were sugar kelp (*Saccharina latissima*), Oarweed (*Laminaria digitate*) and tangle (*Laminaria hyperborea*). A large variety of green algae, red algae, brown algae, and seaweeds were also present in the habitat. The substrate was primarily bedrock and fairly big rocks. The coverage of algae was great and with high biomass.

- Type B: Habitat Type B had an abundance of green sea fingers (*Codium fragile*) and generally a lot of thread-shaped algae (brown, red, and green). A scarce amount of sugar kelp (*Saccharina latissima*) appeared deeper in the water column. Close to the surface, there were different species of littoral fucoids. The substrate was primarily medium-sized round rocks and bedrock near the surface. The algae coverage was less than habitat Type A, with some areas with barren rocks and more scattered distribution of algae, and in turn not as much biomass.

- Type C: Habitat Type C was predominantly dominated by medium-sized (10-50cm) thread-shaped brown, red, and green algae. Near the surface, there were different species of littoral fucoids. The Substrate was mainly sandy bottom, with bedrock close to the surface. The algae coverage was between low and medium with large areas of sand and bedrock without any algae growth, and the algae growth present were scattered and not dense. The biomass was low to medium.

- Type D: Habitat Type D had no apparent dominant species. Generally, there was an even distribution of seaweed, kelp, and red, green and brown thread algae with fucoids residing in the littoral zone. The substrate was either sand, rocks, or bedrock. There was medium to great algae coverage with medium biomass overall.

Habitat2: the category divided the zones into two groups. Zones dominated by kelp species, or zones dominated by different species of thread algae

Sheltered/exposed: Zones facing Huftarøy sheltered from high winds and currents were classified as sheltered habitat. Zones facing the open fjord Bjørnafjorden that are more exposed to high winds and ocean currents were classified as exposed.

2.3 Data collection

The mark–recapture study was conducted over five periods in 2017 and 2018 (table 2). During the start of the project in 2017, 16 fyke nets would be placed each day; this turned out to be a too much material to handle each day. Therefore in 2018 the number of fyke nets placed was reduced to 8 each day over a longer period. Two fyke nets were placed and retrieved in each zone amounting to 64 fyke nets placed and retrieved each period. Baited (shrimp) pots were used in period 5 as a part of another project conducted by the Institute of Marine Research and added as a data supplement.

Table 2: Date of periods and number of fyke nets (pots) placed and retrieved each period, and mean water temperature during each period. There was, unfortunately no temperature measuring devices during period 1.

	Period 1:	**Period 2:**	**Period 3:**	**Period 4:**	**Period 5:**	**Total**
Date	(1.8.17-2.8.17) (8.8.17-10.8.17) (30.8.17-8.9.17)	(11.5.18 – 18.5.18)	(2.7.18 – 9.7.18)	(4.9.18 – 11.9.18)	(24.9.18 – 27.9.18)	
Mean water temperature	NA	10.5 °C	14 °C	16.4 °C	14.4 °C	
Fyke nets placed	(32)(32)(32)	64	64	64	64 (pots)	352

Each sampling day eight fyke-nets were placed and retrieved in different zones at either Lambøya (16 zones) or Bleikjo and Saltkjerholmane (16 zones). We alternated between odd-numbered and even-numbered zones. That way, we avoided fishing in neighboring zones, and all zones were sampled twice throughout each period. We used un-baited fyke nets (gear description; 7,8 m leader, 70 - 65 – 60 – 60 – 55 – 55 – 55 cm diameter from ring 1 to 7, total length 11,3 m, 11 mm mesh size) in order to sample the organisms along the shoreline in periods 1-4. The fyke nets were placed perpendicular to the shoreline at a suitable location in each zone from 0-10 meters depth with the leader net usually reaching the surface. This creates a barrier from the surface that leads passing fish into the net. The fyke-nets were then left overnight soaking for 12-24 hours before being retrieved. The traps were also rigged with a data storage tag with temperature and depth sensors (Star-Oddi; DST centi-TD). A waypoint was created for each placed fyke-net using the GPS mounted on the boat.

In order to monitor the movement of the different species of wrasse in our study location, Passive Integrated Transponder (PIT) tags were used. We used half-duplex PIT tags (12.0 mm x 2.12 mm, Oregon RFID) which are small inert capsules containing passive transponders used to identify individual fishes. The PIT tags were injected into the body cavity of wrasse >100mm in size using a tag injector. Before inserting the tag, the fish was anesthetized using a solution of 50-100mg l-1 tricaine methanesulfonate (MS-222) in a volume of 8-10 l of seawater. Loss of equilibrium was usually achieved within 3 minutes of exposure to the anesthesia depending on species and size. After the insertion of the PIT tag, the fish was placed in a bucket with seawater where it could recover before being released at the location of capture. The tag injector needle was cleaned using 96% ethanol between each injection and replaced after tagging approximately 100 fish or if dulled by handling.

When fyke nets were retrieved, all individual organisms were identified to species and measured for total length to the nearest millimeter. All wrasses were then checked for PIT tags, and the reproductive state of the wrasse was investigated by applying pressure to the abdomen, if ready-to-spawn, the wrasse would release sexual products (milt/roe). This also allowed us to distinguish corkwing and cuckoo wrasse type-2 males (sneaker males) from females. In the absence of sexual products, sex was visually determined. Periods 2, 3 and to some degree period 1 coincided with the wrasse spawning season. Wrasse 100 mm or more in length without previously inserted PIT tag was tagged, and along with the rest of the haul released at the site of capture.

2.4 Analysis

2.4.1 Measuring distance

In order to obtain the distance recaptured wrasse traveled between observations, I used a map-engine provided by the Norwegian Directorate of fisheries called Yggdrasil (https://kart.fiskeridir.no/fiskeri). In Yggdrasil, I used the geodetic coordinate system for Europe 4258 – ETRS 89 LON/LAT, which corresponds to the waypoints obtained from the GPS in the field. The map used had detailed sea-floor topography. The waypoint obtained from each of the individual wrasse observations was plotted into the map engine. A line was then drawn between the observations using a set of assumptions.

- The wrasse swims the shortest route between observations.
- The wrasse avoid depth deeper than 15m

The distance between the observations was then calculated in the map engine down to the centimeter, giving each recaptured wrasse a value in meters.

2.4.2 Statistics

Statistical analyses were performed using the R software version 3.6.0 (R Core Team 2019) and Rstudio (version 1.2.1335). The ggplot2-package (Wickham 2016) was used for visualization of the models. Linear models were checked for homoscedasticity and normality with diagnostic plots. The distance traveled (meters) by the individual wrasses between observations was log-transformed to stabilize the variance for all analyses using distance traveled. It was not taken into consideration that some wrasses were recaptured more than once.

Interspecific differences in movement patterns.

I tested for differences in movement between species using a linear model applying the glm() function with a Gaussian distribution and identity link. Individuals recaptured at Bleikjo were omitted from the analysis due to the small size of the island. This is because the maximum horizontal movement potential is limited by the small size, and not comparable to the other islands. Individuals marked and recaptured during the same sampling period were also excluded on account of the short time between observations and possible influence from recent handling, which might not reflect the true nature of movement by the individual. Cuckoo wrasse, ballan wrasse, and rock cook were also excluded from the analysis. This was because there were too few recaptured individuals across the two islands from these species to make any statistical predictions. A total of 473 recaptures of corkwing and 115 recaptures of goldsinny was used in the analysis. The response variable was the log-transformed distance between observations (Distance traveled) and the explanatory variable corkwing or goldsinny (Species). The model used was:

(log)Distance traveled ~ Species

Intraspecific variation in movement patterns.

Variance in the distance traveled between capture and recapture was examined in detail with linear models by implementing the lm() function in R with Gaussian distribution and identity link. This was done separately and identically for both corkwing and goldsinny. Individuals recaptured on Bleikjo were omitted from the analysis as well as individuals recaptured in the same sampling period. The explanatory variables included in my models were:

- Length: Length is given in millimeters and was the length of the wrasse at the first observation.
- Sex: For corkwing, this includes females, males, and sneaker males. For goldsinny, it includes females and males.
- Island: The location where captured and recaptured, either Lambøya or Saltkjerholmane.
- Time: The duration since last observation, measured in days.

The starting model consisted of all covariates, including interaction effects between length and sex. The starting model was then compared with 17 reduced candidate models comprised of all possible covariate combinations using the Akaike Information Criterion (AIC) to find the best fit model (lowest AIC score). If the difference in the AIC score (ΔAIC) was less than two units between two models, the model with fewer parameters was selected as the primary model since it is considered more parsimonious (Burnham and Anderson 2004). The model with the lowest AIC score was selected as the secondary-model for statistical inference unless selected as the primary model.

To examine if the habitat where the wrasse was first observed effect wrasse movement, the primary model was used as a starting model and candidate models where the different habitat categories were added to the starting model individually was compared using the Akaike Information Criterion. The habitat categories added were either:

- Habitat1: Includes the four different habitat types, Type A, Type B, Type C, and Type D.
- Habitat2: Habitat2 separated zones by either being dominated by Kelp or Thread algae.
- Sheltered/exposed: The zones which faced Huftarøy was categorized as sheltered, and the zones facing the open fjord was categorized as exposed.

Recapture probability

The recapture probability for corkwing and goldsinny was tested using logistic regression models using the function glm() with a binomial distribution and logit link for each species. Tagged and recaptured corkwing (total 4012) and goldsinny (total 2367) from Lambøya and Saltkjerholmane were used in the analysis. Being recaptured or not (1, 0) was the response variable (Value). The explanatory variables used in the model were:

- Length: Length is given in millimeters and was the length of the wrasse when captured.
- Sex: For corkwing, this includes females, males and sneaker males. For goldsinny, it includes females and males.
- Period: The period in which the wrasse was caught. I used periods 1-4 in the analysis. Period 5 was excluded since no fishes were tagged, and only recaptured wrasse was registered, which disrupts the results.
- Island: The location where captured, either Lambøya or Saltkjerholmane.
- Habitat: There were three habitat categories that needed to be considered. Habitat1, Habitat2, and Sheltered/exposed.

Three models were created for each species where the models consisted of all explanatory variables, including one habitat category each. The models were then compared using the Akaike Information Criterion (AIC) to find the best fit model (lowest AIC score). If the difference in the AIC score (ΔAIC) was less than two units between two models, the model with fewer parameters was selected as the primary model since it is considered more parsimonious (Burnham and Anderson 2004).

3 Results

3.1 Overview

Throughout the project, a total of 14868 individual wrasse were caught and measured, 8754 tagged, and 839 individuals were recaptured at either of the three islands (table 3). Of the tagged wrasse, 7.6% was recaptured at least once, and 1.95% was recaptured more than once. Of the 839 wrasse that was recaptured, the majority were corkwing wrasse (n=631), and goldsinny wrasse (n=170). Other species of wrasse had fewer recaptures, ballan wrasse (n=12), cuckoo wrasse (n=5) and rock cook (n=16).

Table 3: The total amount of caught, tagged, and recaptured wrasse of each species and sex during the project.

Wrasse species	**Male**	**Female**	**Sneaker**	**Unknown (NA)**	**Total**
Corkwing					
Caught	2756	3531	101	NA	6388
Tagged	1829	2058	67		3954
Recaptured	301	319	11		631
Goldsinny					
Caught	3344	1900	NA	NA	5244
Tagged	1791	808			2599
Recaptured	123	47			170
Ballan					
Caught	NA	NA	NA	273	273
Tagged				237	237
Recaptured				12	12
Rock cook					
Caught	1166	1002	NA	NA	2168
Tagged	379	639			1018
Recaptured	11	5			16
Cuckoo					
Caught	99	543	11	142	795
Tagged	96	531	10	9	646
Recaptured	2	2	1	0	5
Total					
Caught	7365	6976	112	415	14868
Tagged	4095	4036	77	246	8454
Recaptured	442	373	12	12	839

The distance traveled by each recaptured wrasse at the three islands was generally short (table 4, figure 4). The furthest observed distance traveled was made by a male corkwing that traveled 592.2 meters between capture and recapture. Individuals that traveled < 5 meters were observed for all species. Cuckoo wrasse (11.8m) and goldsinny (42.5m) moved on average shorter distances between observations than corkwing (120.7m), ballan (104.6m) and rock cook (134.8m) which had somewhat similar average horizontal movement.

Table 4: The minimum, maximum, mean, and standard deviation of distance traveled in meters by the different sexes of each species of wrasse.

Wrasse species	**Male**	**Female**	**Sneaker**	**Unknown (NA)**	**Total**
Corkwing wrasse	n=301	n=319	n=11	NA	n=631
min	0.1 m	1.3 m	0.6 m		0.1 m
max	592.2 m	545.5 m	398.7 m		592.2 m
mean	125.6 m	116.9 m	94.9 m		120.7 m
SD	141.1 m	120.7 m	117.2 m		130.7 m
Goldsinny wrasse	n=123	n=47	NA	NA	n=170
min	0.1 m	0.1 m			0.1 m
max	331.6 m	385.7 m			385.6 m
mean	40.5 m	47.8 m			42.5 m
SD	58.1 m	65.8 m			60.2 m
Ballan wrasse	NA	NA	NA	n=12	n=12
min				0.1 m	0.1 m
max				335.6 m	335.6 m
mean				104.6 m	104.6 m
SD				99.4 m	99.4 m
Rock cook wrasse	n=11	n=5	NA	NA	n=16
min	2.2 m	34.5 m			2.2 m
max	286.4 m	393.5 m			393.5 m
mean	82.7 m	249.7 m			134.8 m
SD	78.9 m	147.6 m			127.8 m
Cuckoo wrasse	n=2	n=2	n=1	NA	n=5
min	6.7 m	5.1 m	10.5 m		5.1 m
max	21.3 m	15.4 m	10.5 m		21.3 m
mean	14.0 m	10.3 m	10.5 m		11.8 m
SD	10.3 m	7.3 m	NA		6.6 m

Figure 5: Box plot showing the distance traveled (meters) between capture and recapture by corkwing, goldsinny, ballan, rock cook and cuckoo wrasse recaptured on each of the three islands Bleikjo, Lambøya and Saltkjerholmane.

The mean length of the 6388 caught and measured corkwing was 121.2 mm, and the length range went from 47 mm to 215 mm (figure 2) The mean length of the 5244 caught and measured goldsinny was 103.2 mm, and the length range was from 62 mm to 217 mm (figure 3). Ballan, cuckoo, and rock cook length distributions can be found in the appendix (appendix; figure 8, 9, 10).

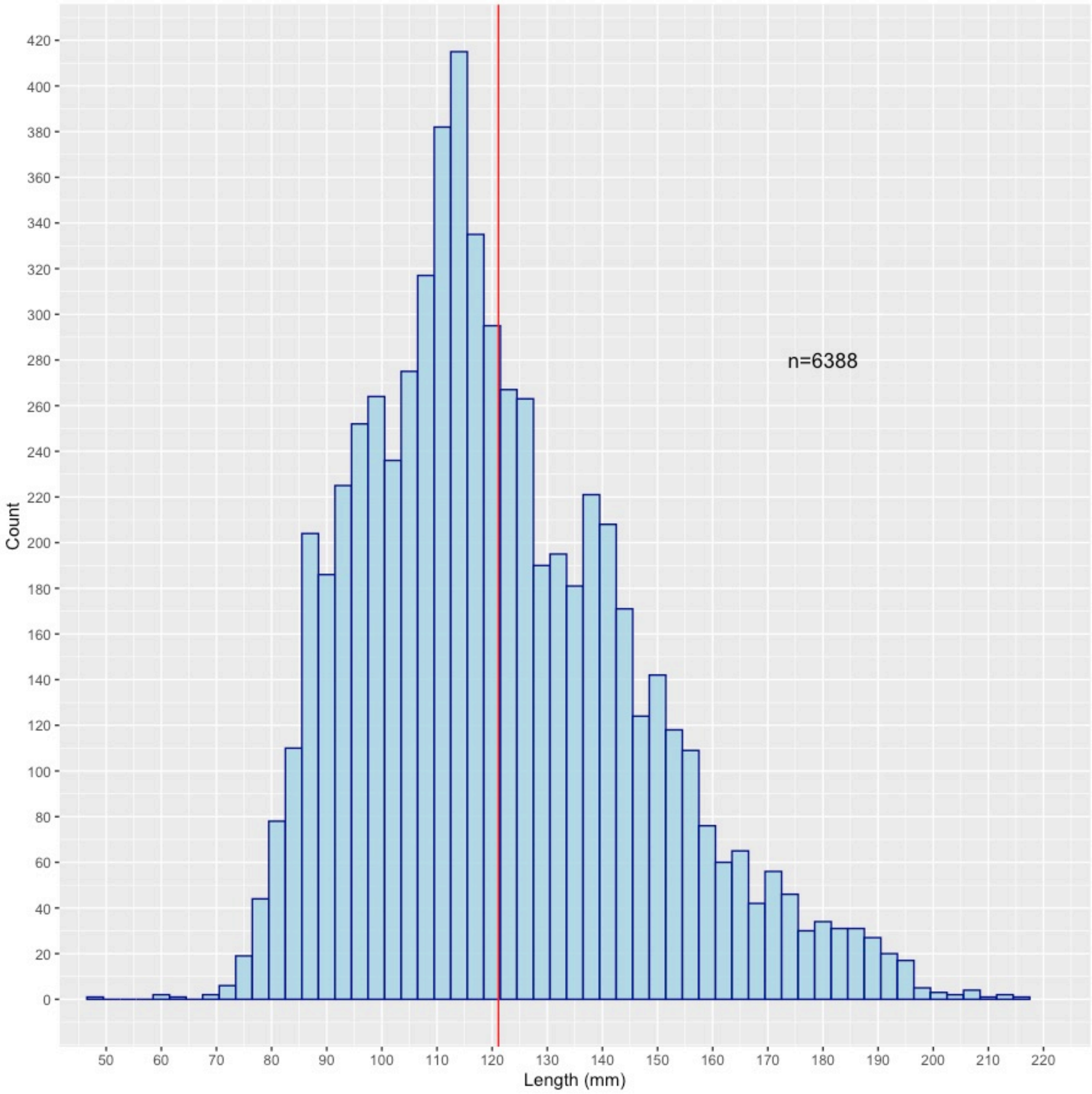


Figure 6: Length distribution of the 6388 caught and measured corkwing from Lambøya, Saltkjerholmane, and Bleikjo. The red line represents the mean size (121.2 mm).

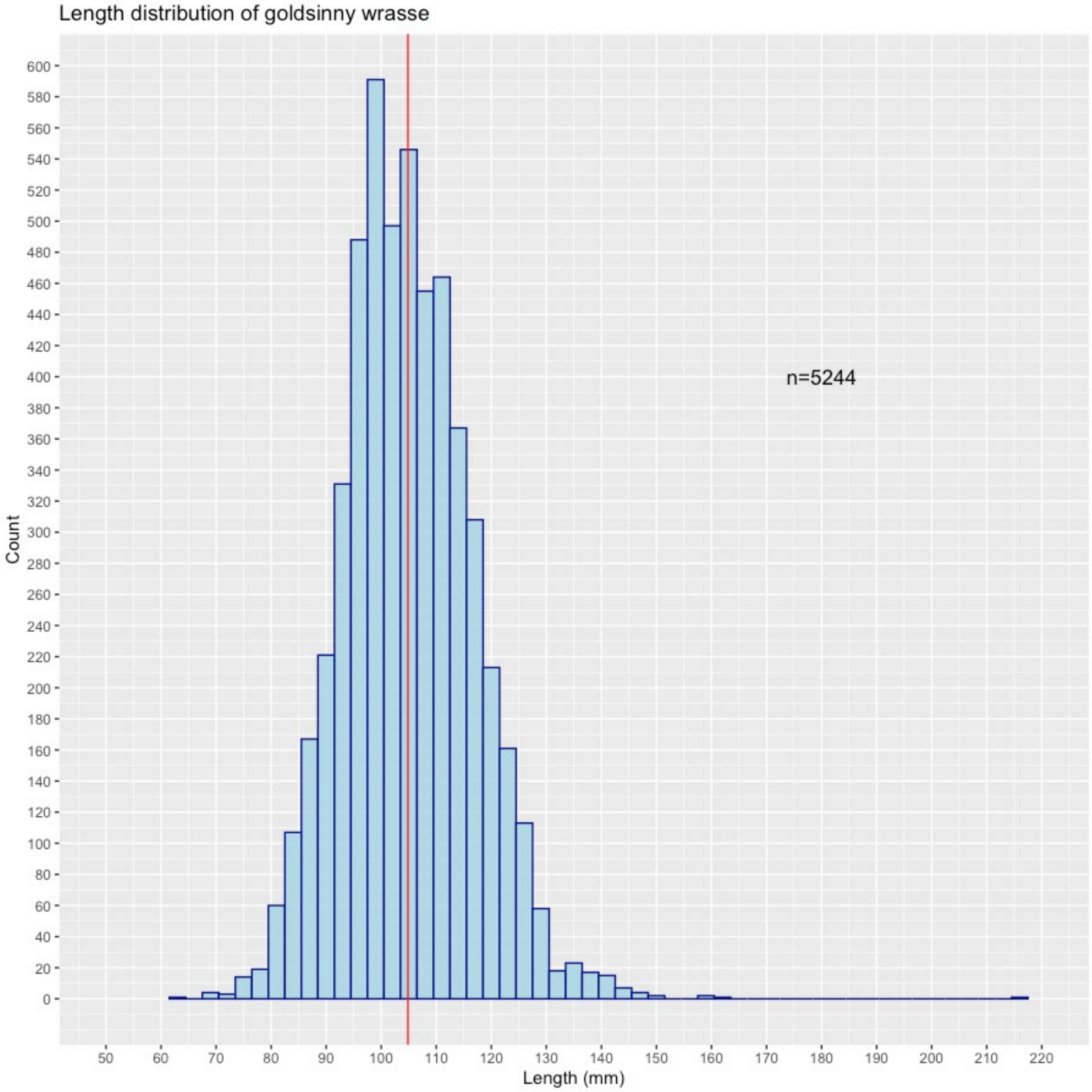


Figure 7: Length distribution of the 5244 caught and measured goldsinny from Lambøya, Saltkjerholmane, and Bleikjo. The red line represents the mean size (103.2mm).

3.2 Movement between islands

None of the recaptured wrasses was found to be moving between Lambøya, Bleikjo, or Saltskjærholmane (figure 4). The distance between the islands is approximately 470 meters from Lambøya to Bleikjo separated by depths reaching 80 meters, and 270 meters between Bleikjo and Saltkjerholmane with depths reaching 25 meters.

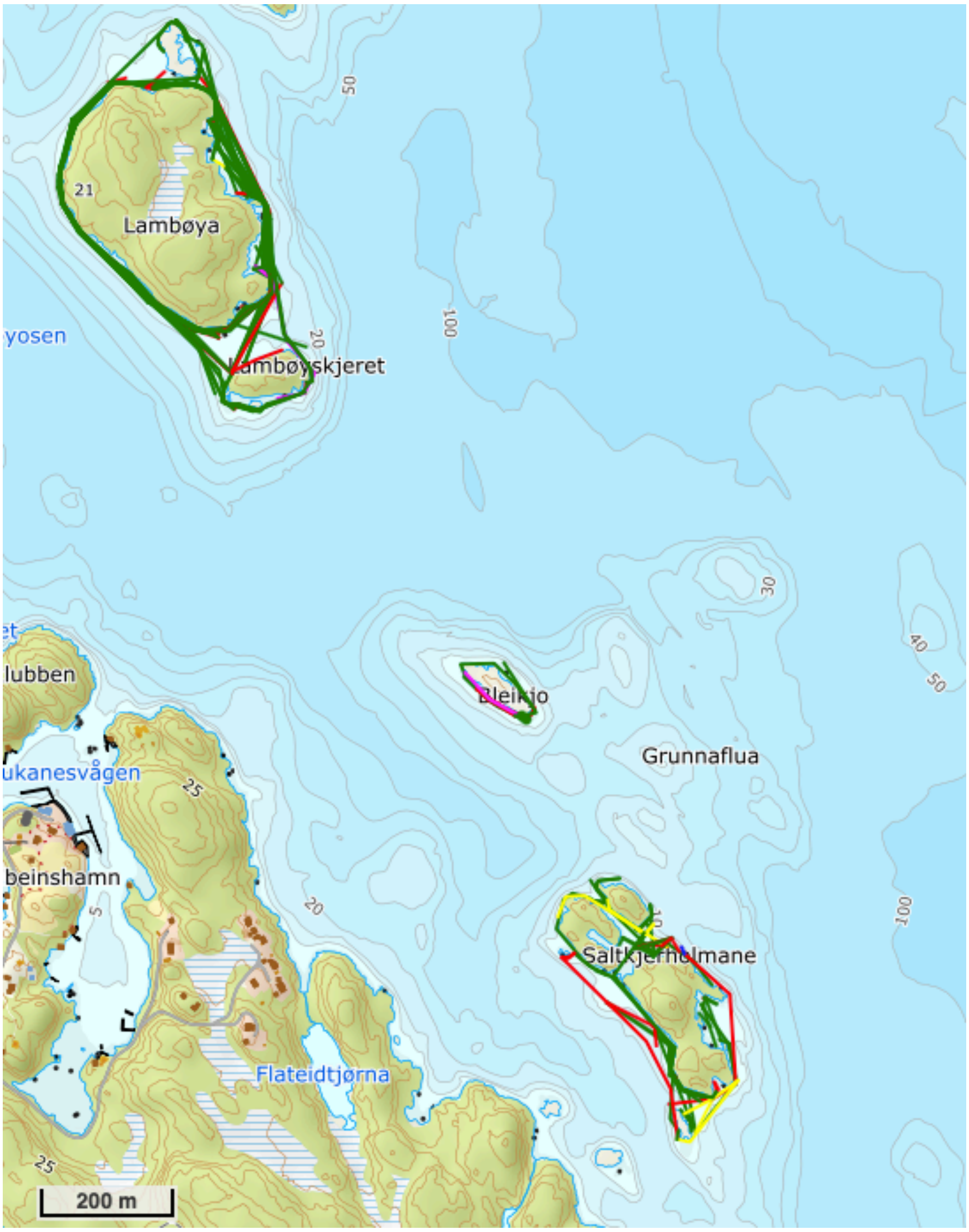


Figure 8: Map of the three islands used in this study with a random selection of 450 individual wrasse pathways. Each colored line represents the distance traveled by one wrasse from the location of capture to location where recaptured. Corkwing wrasse = green line, goldsinny wrasse = red line, ballan wrasse = yellow line, rock cook = purple line and cuckoo wrasse = blue line. The Norwegian Directorate of fisheries provided the map and map engine (https://kart.fiskeridir.no/fiskeri.).

3.3 Interspecific differences in movement patterns

A total of 473 corkwing wrasse and 115 goldsinny wrasse recaptures were used to analyze whether the two species have different movement patterns. Ballan, rock cook, and cuckoo wrasse were excluded from the analysis due to the small sample size. Wrasse recaptured on Bleikjo was not used in the analysis, and wrasse caught repeatedly during the same period were also excluded from further analysis.

A linear model with distance traveled between subsequent observations as the response variable, and species (corkwing and goldsinny) as the explanatory variable was constructed (table 7). The parameter estimates from the linear model showed that corkwing traveled on average significantly longer distances between capture and recapture than goldsinny (table 7, figure 4).

Table 5: Summary of the interspecific movement model on distance traveled between capture and recapture with species (corkwing and goldsinny). The response variable is log-transformed.

Interspecific movement - Corkwing and goldsinny				
Variable	Estimate (β)	Std. Error	T value	P value
(Log) Distance traveled (meters)				
Intercept	4.07	0.07	57.87	< 0.001 ***
Goldsinny	-1.48	0.16	-9.27	< 0.001 ***
Reference levels = Corkwing				

3.4 Intraspecific variation in movement patterns

3.4.1 Corkwing

A total of 473 recaptured corkwing was used for the analysis (figure 4). The distance traveled by each wrasse was used as the response variable in the linear models. Length (mm) at first capture, Sex (male, female, sneaker male), Time since previous observation (days) and Island of recapture (Saltkjerholmane, Lambøya) were used as explanatory variables.

Model selection was used in order to discover the best fit model (table 8). The model with interaction between Length and Sex paired with Island as an additive effect had the lowest AIC score (1577.3). The model with Length and Island as additive effects had an AIC score within two units of the lowest scoring model (ΔAIC: 1.78) and was chosen as the primary model for statistical inference because it had fewer estimated parameters (table 9). The model with the lowest AIC score was also used for statistical inference (table 10).

Table 6: Model selection of linear models on distance traveled (meters between observations) for corkwing wrasse. The table show model structure, the number of estimated parameters, the AIC score, and the differences between specified models with the model with the lowest AIC score (ΔAIC). The model with the lowest AIC score is used for statistic inference (in **bold**) unless ΔAIC is less than two units between two models, then the model with fewer parameters is selected.

Model structure	Parameters	AIC	ΔAIC
(log) Distance traveled			
Length * Sex + Island + Time	8	1579.05	1.75
Length * Sex + Island	7	1577.3	0
Length * Sex + Time	7	1635.37	58.07
Length * Sex	6	1634.47	57.17
Length + Sex + Island + Time	6	1582.52	5.22
Length + Sex + Time	5	1640.24	62.94
Length + Sex + Island	5	1580.89	3.59
Length + Sex	4	1639.59	62.29
Length + Time	3	1637.67	60.37
Length + Island	**3**	**1579.08**	**1.78**
Length	2	1637	59.7
Sex + Island + Time	5	1591.07	13.77
Sex + Time	4	1643.75	66.45
Sex + Island	4	1589.46	12.16
Sex	3	1643.12	65.82
Island + Time	3	1589.48	12.18
Island	2	1587.86	10.56
Time	2	1641.38	64.08

The primary model for corkwing movement showed that corkwing moved longer distances between observations with increasing body length (table 10, figure 8). The model estimates that with an increase of 1 mm in body length, corkwing wrasse moved approximately 1 meter further between capture and recapture. The model also shows that corkwing wrasse moves significantly shorter distances between observations on Saltskjærholmane than on Lambøya.

The secondary model showed that sneaker males moved significantly shorter than females and males, and that sneaker males had a significant interaction effect between sex and length, showing that the distance traveled increased with increased body length (table 11, figure 9). Only nine sneaker males were used in this model, and this small sample size may have skewed the results somewhat. Distance traveled by the individual corkwing significantly increases between observations with increasing body length. All corkwing moved significantly shorter on Saltkjerholmane than Lambøya.

Table 7: Summary of the primary model on distance traveled between capture and recapture by corkwing with Length and Island as additive effects. The response variable is log-transformed.

Primary model - Corkwing				
Variable	Estimate (β)	Std. Error	T value	P value
(Log) Distance traveled				
Intercept	3.35	0.39	8.65	< 0.001 ***
Length	0.01	0.00	2.85	0.005 **
Island Saltkjerholmane	-0.98	0.12	-8.10	< 0.001 ***
Reference level =Island Lambøya				

Table 8: Summary of the secondary model on distance traveled by corkwing with interaction effects between length and sex, and length and Island as additive effects. The response variable is log-transformed.

Secondary model - Corkwing				
Variable	Estimate (β)	Std. Error	T value	P value
(Log) Distance traveled				
Intercept	3.49	0.48	7.25	< 0.001 ***
Length	0.008	0.004	2.12	0.035 *
Sex Female	-0.007	0.82	-0.01	0.993
Sex Sneaker	-12.07	4.23	-2.85	0.005 **
Island Saltkjerholmane	-0.95	0.12	-7.88	< 0.001 ***
Length:Sex Female	-0.0006	0.006	-0.10	0.918
Length:Sex Sneaker	0.10	0.04	2.73	0.007 **
Reference level = Island Lambøya and Sex male				

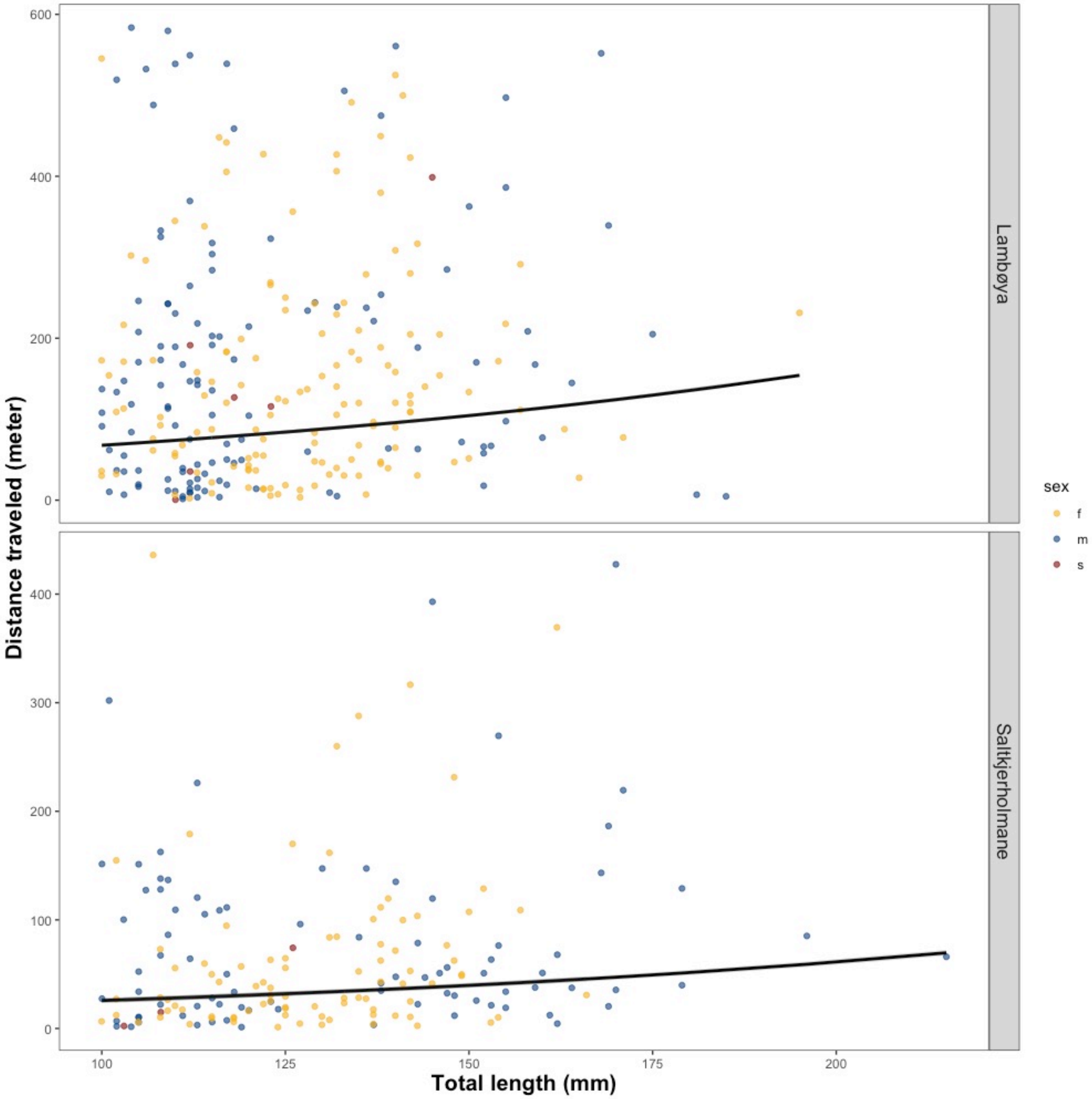


Figure 9: The distance traveled by corkwing plotted against body length. Each sex is assigned an individual color (female = yellow, male = blue, sneaker = red). The data is separated between the two relevant islands, Lambøya and Saltskjærholmane). Lines show predicted values from the primary model, which show the correlation between distance traveled and length.

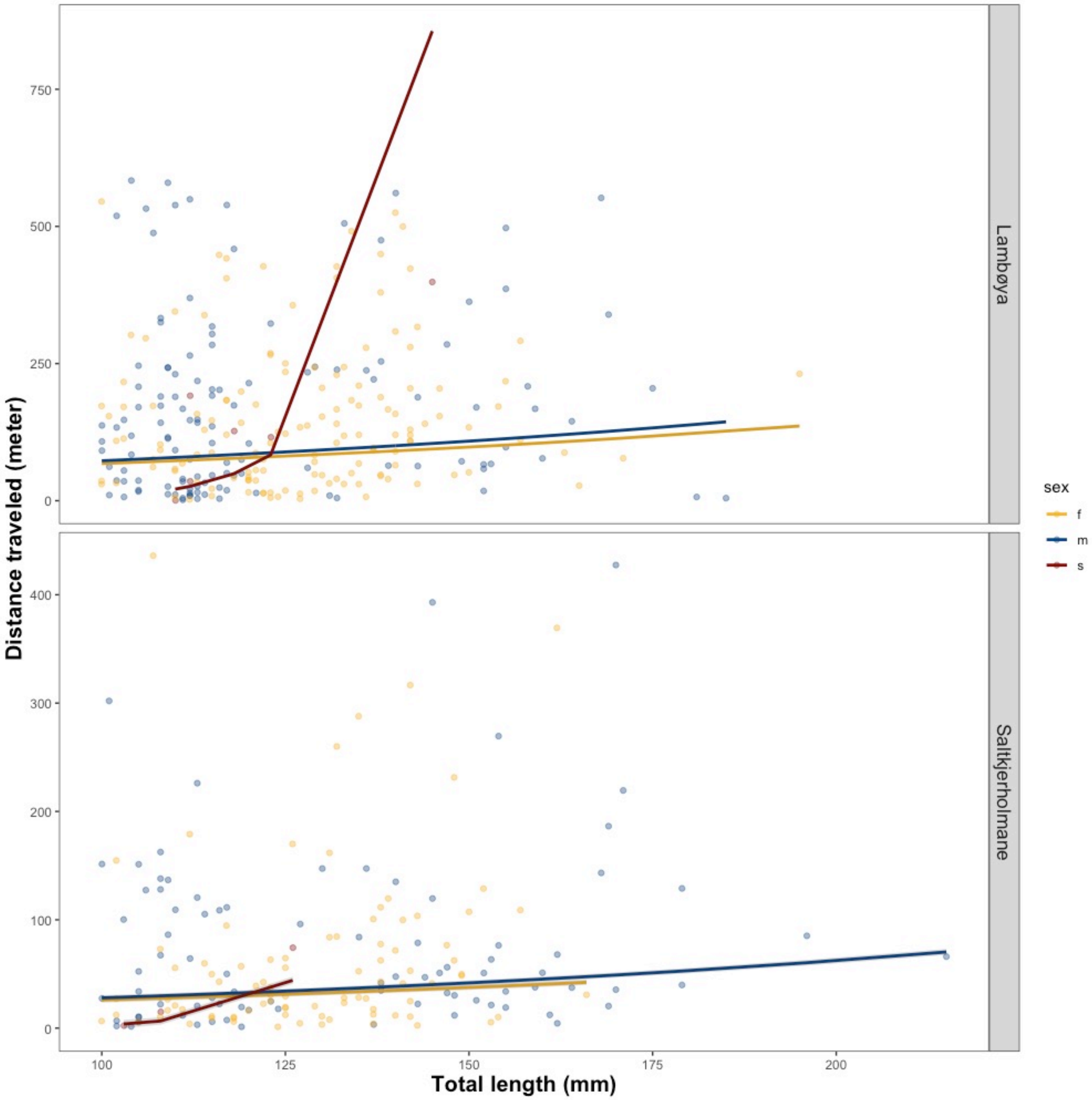


Figure 10: The distance traveled by corkwing plotted against body length. Each sex is assigned an individual color (female = yellow, male = blue, sneaker = red). The data is separated between the two relevant islands, Lambøya and Saltskjærholmane). Lines show predicted values from the primary model, which show the correlation between distance traveled and length for each sex.

To investigate whether the habitat where the corkwing was captured had any significant effect on the distance traveled between capture and recapture, I used model selection where the previously selected primary model was applied as the starter model, and candidate models with the different habitat categories were added to the starter model and compared (table 12). The model with the added Habitat2 category had the lowest AIC score and was further analyzed (table 13).

Table 9: Model selection of linear models on habitat effects on distance traveled (meters between observations) for corkwing wrasse. The table show model structure, the number of estimated parameters, the AIC score, and the differences between specified models with the model with the lowest AIC score (ΔAIC). The model with the lowest AIC score is used for statistic inference (in **bold**) unless ΔAIC is less than two units between two models, then the model with fewer parameters is selected.

Model structure	Parameters	AIC	ΔAIC
(log) Distance traveled			
Length + Island	3	1579.08	4.93
Length + Island + Habitat 1	6	1578.81	4.66
Length + Island + Habitat 2	**4**	**1574.15**	**0**
Length + Island + Sheltered/exposure	4	1575.41	1.26

The habitat model shows that corkwing wrasse moved significantly longer distances if it was first caught in a habitat dominated by thread algae (table13).

Table 10: Summary of the habitat model with the Habitat2 category as an added additive effect to the primary model on distance traveled by corkwing. The response variable is log-transformed.

Habitat model - Corkwing				
Variable	Estimate (β)	Std. Error	T value	P value
(Log) Distance traveled				
Intercept	3.32	0.39	8.58	< 0.001 ***
Length	0.008	0.003	2.50	0.013 *
Island Saltkjerholmane	-0.88	0.13	-6.98	< 0.001 ***
Habitat thread algae	0.33	0.13	2.63	0.009 **
Reference levels = Island Lambøya and habitat kelp				

3.4.2 Goldsinny

A total of 115 recaptured goldsinny was used for the analysis (figure 4). The distance traveled by each wrasse was used as the response variable in the linear models. Length (mm) at first capture, sex (female or male), time since first observation (days) and Island of recapture (Saltkjerholmane, Lambøya) were used as explanatory variables.

Model selection was used in order to discover the best fit model (table 14). The model with Island and Time as additive effects had the lowest AIC score (495.52). The model with Island as an additive effect had an AIC score within two units of the lowest scoring model (ΔAIC: 1.9) and was chosen as the primary model for statistical since it had fewer parameters (table 15). The model with the lowest AIC score was also used for statistical inference (table 16).

Table 11: Model selection of linear models on log transformed distance traveled (meters between observations) for goldsinny wrasse. The table show model structure, the number of estimated parameters, the AIC score and the differences between specified models with the model with the lowest AIC score (ΔAIC). The model with the lowest AIC score is used for statistic inference (in **bold**) unless the ΔAIC score is less than two units between two models, then the model with fewer parameters is selected.

Model structure	Parameters	AIC	ΔAIC
(log) Distance traveled			
Length * Sex + Island + Time	6	496.89	3.27
Length * Sex + Island	5	497.09	3.47
Length * Sex + Time	5	500.36	6.74
Length * Sex	4	499.94	6.32
Length + Sex + Island + Time	5	496.1	2.48
Length + Sex + Time	4	499.6	5.98
Length + Sex + Island	4	497.7	4.08
Length + Sex	3	500.39	6.77
Length + Time	3	497.68	4.06
Length + Location	3	495.71	2.09
Length	2	498.39	4.77
Sex + Island + Time	4	495.58	1.96
Sex + Time	3	500.62	7
Sex + Island	3	497.51	3.89
Sex	2	501.69	8.07
Island + Time	3	493.62	0
Island	**2**	**495.52**	**1.9**
Time	2	498.63	5.01

The primary model for goldsinny movement showed that goldsinny moves on average shorter distances between observations on Saltkjerholmane than Lambøya (table 15).

The secondary model for goldsinny movement showed that as well as moving shorter distances on Saltkjerholmane, goldsinny movement increase with increasing time between subsequent observations (table 16, figure 10). On average, a one-meter increase with each day since the last observation.

Table 12: Summary of the best fit model with fewest parameters within two units of the model with lowest AIC score (ΔAIC=1.89). The model has Island as an additive effect on the log transformed distance traveled by goldsinny.

Primary model - Goldsinny				
Variable	Estimate (β)	Std. Error	T value	P value
(log) Distance traveled				
Intercept	3.02	0.25	11.85	< 0.001 ***
Island Saltkjerholmane	-0.96	0.39	-2.50	0.0139 *
Reference level =Island Lambøya				

Table 13: Summary of the secondary model with the lowest AIC score (AIC=493.6). The model has Island of capture and Time since last capture as additive effects on the log transformed distance traveled by goldsinny.

Secondary model - Goldsinny wrasse				
Variable	Estimate (β)	Std. Error	T value	P value
(log) Distance traveled				
Intercept	2.56	0.34	7.54	< 0.001 ***
Time	0.002	0.001	1.96	0.0519 .
Island Saltkjerholmane	-1.01	0.39	-2.49	0.0139 *
Reference level =Island Lambøya				

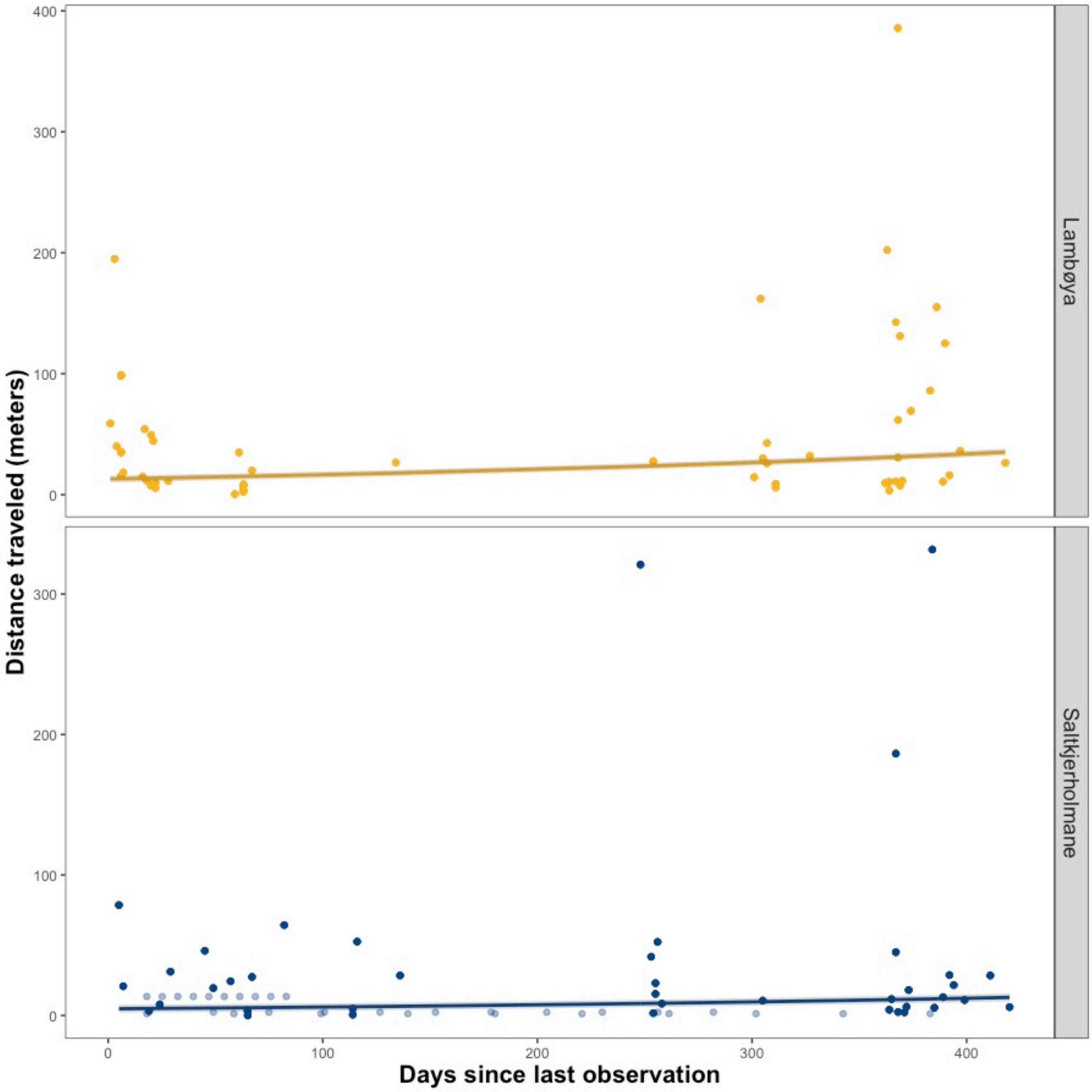


Figure 11: The distance traveled by goldsinny wrasse plotted against days since last capture. The data is separated between the two Islands, Lambøya and Saltskjærholmane. A dummy dataset using 10 dummy observations per factor combination using the maximum and minimum range to avoid extrapolation was used to better visualize the predicted values from goldsinny movement model 2 (lines). The predicted line show correlation between the distance traveled with amount of time passed.

To see whether the habitat where the goldsinny was captured had any significant effect on the distance traveled between capture and recapture, I used model selection where the previously selected primary model was applied as the starter model, and candidate models with the different habitat categories added to the starter model were compared (table 17). The primary model with Island as an additive effect proved to be the best model, implying that the habitat where the goldsinny was caught had no significant impact on the movement observed between capture and recapture. The next best model (Island + sheltered/exposure) was tested and showed no significant effects of habitat variables.

Table 14: Model selection of linear models on habitat effects on distance traveled (meters between observations) for goldsinny wrasse. The table show model structure, the number of estimated parameters, the AIC score and the differences between specified models with the model with the lowest AIC score (ΔAIC). The model with the lowest AIC score is used for statistic inference (in **bold**) unless ΔAIC model is less than two units between two models, then the model with fewer parameters is selected.

Model structure	Parameters	AIC	ΔAIC
(log) Distance traveled			
Island	**2**	**495.52**	**0**
Island + Habitat 1	5	496.69	1.17
Island + Habitat 2	3	497.42	1.90
Island + Sheltered/exposure	3	496.05	0.53

3.5 Recapture probability

To see what factors influenced the probability of recapturing corkwing and goldsinny, logistic regression models were made for each species where whether recaptured or not was the response variable (Value) and length at capture (Length), island captured (Island), period captured (Period) and habitat captured (Habitat1, Habitat2, Sheltered/exposed) were explanatory variables. In this analysis all tagged and recaptured corkwing and goldsinny from Lambøya and Saltkjerholmane was used respectively. Wrasses recaptured in the same sampling period was included. Wrasse recaptured in Period 5 were excluded since the period was supplementary and no fishes except recaptured wrasse were registered.

Corkwing

Model selection was used in order to discover which habitat category provided the best fit model (table 5). The model with Habitat1 as the additional additive effect had the lowest AIC score (3042.39) and used for statistical inference (table 6).

Table 15: Model selection of logistic regression on recapture probability for corkwing. The table show model structure, the number of estimated parameters, the AIC score, and the differences between specified models with the model with the lowest AIC score (ΔAIC). The model with the lowest AIC score is used for statistic inference (in **bold**) unless ΔAIC is less than two units between two models, then the model with fewer parameters is selected.

Model structure	Parameters	AIC	ΔAIC
Value			
Length + Period + Island + Sex + Habitat1	**11**	**3042.39**	**0**
Length + Period + Island + Sex + Habitat2	9	3053.86	11.47
Length + Period + Island + Sex + Sheltered/exposed	9	3067.22	24.83

The model for corkwing recapture probability show that there was a significant length effect, where it was more likely to be captured with increased length (table 5). There was no effect of Period 2, but higher probability of being recaptured in Period 3 and 4. There was also increased probability of being captured at Lambøya compared to Saltkjerholmane and in habitats dominated by thread algae compared to Kelp. There was no effect of sex on recapture probability.

Table 16: Summary of the selected logistic regression model on corkwing recapture probability.

Recapture probability - Corkwing				
Variable	Estimate (β)	Std. Error	Z value	P value
Recapture probability				
Intercept	-4.46	0.30	-14.57	< 0.001 ***
Length	0.02	0.002	7.47	< 0.001 ***
Period 2	0.17	0.17	0.99	0.32
Period 3	0.38	0.15	2.48	0.013 *
Period 4	0.41	0.11	3.70	< 0.001 ***
Island Lambøya	0.27	0.11	2.36	0.018 *
Sex Male	-0.04	0.10	-0.40	0.68
Sex Sneaker	-0.13	0.40	-0.33	0.74
Habitat1 Type B	0.68	0.12	5.86	< 0.001 ***
Habitat1 Type C	0.05	0.26	0.18	0.85
Habitat1 Type D	0.11	0.14	0.78	0.43
Reference level = Period 1, Island Saltkjerholmane, Sex female and Habitat1 Type A.				

Goldsinny

Model selection was used in order to discover which habitat category provided the best fit model (table 7). The model with Habitat2 as the additional additive effect had the lowest AIC score (839.46) and used for statistical inference (table 8).

Table 17: Model selection of logistic regression on recapture probability for goldsinny. The table show model structure, the number of estimated parameters, the AIC score, and the differences between specified models with the model with the lowest AIC score (ΔAIC). The model with the lowest AIC score is used for statistic inference (in **bold**) unless ΔAIC is less than two units between two models, then the model with fewer parameters is selected.

Model structure	Parameters	AIC	ΔAIC
Value			
Length + Period + Island + Sex + Habitat1	10	843.59	4.13
Length + Period + Island + Sex + Habitat2	**8**	**839.46**	**0**
Length + Period + Island + Sex + Sheltered/exposed	8	847.71	8.25

The model for goldsinny showed that there was a significant increase in probability of being recaptured in Periods 2, 3 and 4, and being captured in the thread algae habitat as opposed to kelp dominated habitat (table 6). There were no effect of length, islands or sex on probability of being recaptured.

Table 18: Summary of the selected logistic regression model on goldsinny recapture probability.

Recapture probability - Goldsinny				
Variable	Estimate (β)	Std. Error	Z value	P value
Recaptured/not recaptured				
Intercept	-3.65	1.54	-2.35	0.02 *
Length	-0.006	0.01	-0.46	0.65
Period 2	1.22	0.38	3.23	0.001 **
Period 3	1.02	0.33	3.08	0.002 **
Period 4	1.41	0.25	5.60	< 0.001 ***
Island Lambøya	0.05	0.21	0.23	0.82
Sex Male	0.23	0.22	1.01	0.32
Habitat2 Thread algae	0.67	0.21	3.14	0.002**
Reference level = Period 1, Island Saltkjerholmane, sex female and Habitat2 kelp.				

4 Discussion

During this mark-recapture experiment, the five wrasse species found at the three islands; Lambøya, Bleikjo, and Saltkjerholmane located in western Norway were analyzed in order to identify interspecific differences and intraspecific variation in movement patterns by using life-history traits and environmental factors. Results were then considered concerning wrasse management.

4.1 Wrasse movement

Wrasse in temperate regions is usually found thriving in shallow waters, with overlapping distribution in the water column when multiple species are present (Thangstad 1999; Hilldén 1983). The observed movement throughout this study indicates that movement is mainly horizontal and short. This is emphasized by the observation that no wrasses moved between the three islands. The stretches of open water that separates Lambøya from Bleikjo and Saltkjerholmane is approximately 470 and 870 meters respectively, with depths reaching 80 meters. The distance that separates Bleikjo from Saltkjerholmane is relatively short in comparison (270 meters). In addition, there are underwater skerries creating a connecting ridge between the two islands with only one short stretch of ocean where depths reach 25 meters. It is therefore natural to assume that wrasses disperse horizontally by following the shoreline opposed to vertically where they might need to traverse deep waters to find suitable habitats.

The five species of wrasse in this study except for goldsinny have benthic eggs, although the majority of eggs released during goldsinny spawning sink to the seafloor (Hilldén 1981; Costello 1991). The absence of traveling between islands, especially between Bleikjo and Saltkjerholmane suggests that gene flow between the islands is determined by pelagic larval dispersal and to some degree egg dispersal (goldsinny). More importantly, recruitment is dependent on the spawning potential at each location and environmental conditions affecting dispersal and settlement of fish larvae. This is reflected by findings that corkwing has highly differentiated populations and display a moderate isolation-by-distance pattern in genetic diversity in western Norway (Gonzalez, Knutsen, and Jorde 2016), while goldsinny has a low genetic divergence between population (Jansson et al. 2017).

4.2 Interspecific differences in movement patterns

When comparing the observed movement between the species of wrasse, I found that corkwing wrasse moved significantly longer than goldsinny. In this comparison Bleikjo was not included since the small size of the island limit the potential for movement, and there would be no expected differences between the two species.

There were unfortunately not enough recaptures of the other species to make any statistically supported comparisons with ballan, rock cook and cuckoo wrasse, however, the lack of recaptures tell something of the way these fishes move and behave. The observed distances traveled indicate that horizontal movement at the study location was local for all species. The longest observed distance traveled for any one recaptured wrasse was 592 meters, the average for the five species was generally much shorter. This is likely influenced by the fact that all the wrasses in this study display territoriality (Costello 1991). Goldsinny and cuckoo wrasse had the shortest horizontal movement on average, while corkwing, ballan, and rock cook had somewhat longer movement (table 4, figure 5).

The finding that corkwing moved significantly longer distances than goldsinny align with previous assumptions (Hilldén 1981; Costello, Darwall, and Lysaght 1995; Geoffrey W. Potts 1985). Corkwing has an overall higher growth rate and bigger size than goldsinny (Sayer, Gibson, and Atkinson 1996b), and in turn, the area needed to sustain favorable conditions increase (Grüss et al. 2011). Corkwing territories have been observed to be able to exceed 15m^2 (Costello, Darwall, and Lysaght 1995), whereas the territory of goldsinny males have been found to range from 0.5 to 2m^2 (Hilldén 1981), although larger territories (~ 10m^2) have also been found in rocky areas with low goldsinny densities (Collins 1996). Differences in territory sizes might explain some of the observed differences in horizontal movement between corkwing and goldsinny. During the spawning season male goldsinny invest considerable time and energy in guarding and patrolling their small territory, whereas female goldsinny remain within the confines of the territory throughout, and sometimes after the spawning season (Hilldén 1981). While corkwing males usually stay within close proximity to the constructed nest, females and sneaker males may move more freely (K. T. Halvorsen, Sørdalen, et al. 2017).

Corkwing is also found to prefer shallow and protected algae-covered areas in depths <5 meters, although they can occur in depths of 15-18 meters (Sayer, Treasurer, and Costello

1996; Costello 1991; Skiftesvik et al. 2015). If this depth preference is a limiting factor when selecting habitat, this will likely make the area occupied by corkwing narrower and follow the shoreline horizontally. Goldsinny is found from the intertidal zone down to depths of 50 meters and, the limiting factor for goldsinny distribution appears to be the presence of refuge in the form of a shelter hole, cave or crevice (Sayer, Gibson, and Atkinson 1993). Therefore, the low observed horizontal movement might be influenced by the possibility of inhabiting deeper areas, and that they also may move more vertically in the water column.

Ballan wrasse were the least abundant species in our catches constituting 1.8% of the wrasse catch. A previous study on the distribution of wrasse in Lysefjord, not far from my study site found similar proportions (>2% of the catches) of ballan compared to the other species of wrasse (Skiftesvik et al. 2015). The home range of ballan is small and segregated by size, where smaller individuals are found to move longer than the highly territorial males (Villegas-Ríos, Alós, et al. 2013).

Cuckoo males are territorial and diandric protogynous hermaphrodites, where one male can maintain a harem of up to 40 females depending on the size of the territory (Hilldén 1984; Dipper and Pullin 1979). This is reflected in the sex ratio observed in the overall catch during the project. Of the 795 captured cuckoo wrasses, only 12.5 % were males. There were, however, only five recaptures during the project; this was the lowest return rate of recaptures relative to tagged fish. The distances traveled by the recaptured cuckoo wrasse was the overall lowest observed for all species (5.1 - 21.3 meters). I suggest since cuckoo wrasse reportedly prefer depths greater than 10 meters associated with the algae belt (Lythgoe and Lythgoe 1992), that movement vertically along the seafloor is maybe more common for this species.

Rock cook was the third most captured species of wrasse. Despite a large number of tagged individuals, only 16 were recaptured (1.5%). The average distance moved between observations for these individuals were 135 meters, which is the highest of the five wrasse species. It has previously been observed that rock cook congregates in shoals and is more contagiously distributed than the other four species (Hilldén 1984; Thangstad 1999; Costello, Darwall, and Lysaght 1995). This aggregation into shoals could be a measure to overcome the strong territoriality displayed by the other wrasses, or as a refuge from predators. Shoaling behavior could also explain the longer overall horizontal movement, as more individuals would need a larger area to forage, and the disparities in the catches of rock cook (personal observation), a phenomenon also observed by Thangstad (1999).

4.3 Intraspecific variation in movement patterns

In this section I look at the observed variation in movement patterns within the species. Unfortunately, there was not enough recaptures to perform statistical analysis to investigate the intraspecific variation in movement patterns for ballan wrasse, rock cook and cuckoo wrasse. Some intraspecific variation was however observed for ballan wrasse.

When analyzing the intraspecific variation in movement patterns for corkwing and goldsinny I found that both species moved shorter on Saltkjerholmane than Lambøya. This is likely due to the overall size of the islands, as Lambøya have ~2.3 km of shoreline, and Saltkjerholmane have ~ 1.7 km. The shorter shoreline on Saltkjerholmane might provide less potential for long movements. Saltkjerholmane is also arguably more complex in its shape than Lambøya, with multiple small islands clustered around a shallow lagoon. And there is generally a gentler incline around the island with shallow areas that stretch further from the shoreline than on Lambøya. This could allow movement to be directed more vertically from the shoreline in addition to horizontally as corkwing and goldsinny is thought to prefer the shallows (Thangstad 1999; Hilldén 1984)

4.3.1 Corkwing

I found that corkwing moved longer distances when larger. An increase in home range when a fish grows larger is commonly observed for territorial fishes (Grüss et al. 2011). With a bigger size, there is an increase in energy requirements, and as a result the amount of time and space spent searching for food increase (Wootton 1998). With increasing size, fish might also be less prone to predation, which allows the fish to move more freely (Secor 2015).

In corkwing wrasse, it is the nesting male which attain the largest sizes (K. T. Halvorsen et al. 2016). The nesting male is fiercely territorial during the spawning season and maintains and defend a small territory in association with a nest (Geoffrey W. Potts 1985). This high site-fidelity would imply that there was a negative interaction effect between sex and length on the distance traveled for nesting males. However, there were no such effects, likely because the movement interval I observed could span over multiple periods during the project. Therefore, the variation in home range that is expected with the spawning season is masked by the movement made outside of the spawning season. It is, however, characteristic that the home range of established territories expands with an increase in size for territorial fish (Grüss et al. 2011), which could also help explain the observed length effect.

Corkwing was found to move significantly shorter on Saltkjerholmane than on Lambøya. Besides the fact that the two islands vary in size, the difference in movement on the two islands suggests that there could be other factors influences the observed movement such as differences in wrasse densities and/or habitat qualities.

The overall densities of corkwing on the two islands were relatively similar albeit somewhat lower on Lambøya (Appendix; table 2). This might suggest that there were no pronounced differences in intraspecific competition for resources on these islands. Corkwing has, however, been found to have lower growth rates when there is a high density of goldsinny (Vik 2019) The high density of goldsinny compared to corkwing on Lambøya suggest that corkwing and goldsinny had to compete over resources. This would in turn increase the corkwing home range since food and shelter would be patchier.

The topography of Saltkjerholmane and the surrounding shallows might also provide an overall more suitable habitat for corkwing. Corkwing has been reported to prefer <5 meter shallow waters (Sayer, Treasurer, and Costello 1996; Costello 1991; Skiftesvik et al. 2015), and if there was no density constraints on habitat selection, a number of high quality habitats with food and shelter might have been available. A high-quality habitat is likely to make the home range smaller, and thus reducing the observed distance traveled for corkwing

The secondary model found that sneaker males move shorter distances than nesting males and females, and that sneaker males move longer distances with increasing length. The results from the secondary model should be looked at with scrutiny because of the small number of sneaker males in the analysis. I hypothesize that the two patterns of being relatively stationary vs. moving further with increase length might reflect two different strategies. There should be a considerable risk with trying to steal fertilization from an aggressive nesting male. Halvorsen (personal observation) have witnessed attacks by nesting males on sneaker males approaching the nest, as well as nesting males possibly recognizing sneaker males from previous encounters. When small and vulnerable the strategy of remaining within a territory if a successful “deception” of the nesting male is achieved, might provide a less overall risk of an aggressive and fatal encounter and a higher probability of successfully reproducing. The increase in movement with increasing length might reflect a strategy where when a certain size is reached, the sneaker male is less likely to be fatally injured, and the potential gain of fertilizing multiple eggs, in multiple nests outweigh the risk of being injured.

When analyzing the effect of habitat on corkwing movement, I found that the distance traveled between observations was longer when the fish was previously observed in habitats dominated by thread algae. Thread algae habitats were predominant in the most sheltered areas on both Lambøya and Saltkjerholmane, and previous studies on the distribution of temperate wrasses have found that corkwing is more abundant in sheltered areas (Skiftesvik et al. 2015). Areas with high densities of conspecifics is likely to increase the competition for the same resources (Grüss et al. 2011), and sheltered areas are supplied with fewer nutrients and food compared to exposed areas (Leigh et al. 1987). The increase in distances traveled from this habitat might be that an increase in home range was necessary to attain enough recourses for the individual fish. It could also be the opposite; that the kelp habitats provide a more complex habitat with more resources, which makes long travels unnecessary.

While immature fish, sneaker males, and females are able to move more freely during the spawning season, nesting males are occupied with their nests (K. T. Halvorsen, Sørdalen, et al. 2017). A majority of the time spent on movement during this time is allocated to maintaining and retrieving suitable materials for the nests (Geoffrey W. Potts 1985). The increase in distance traveled could have been influenced by a lack of preferred algae for nest building, and bigger areas were searched in order to find the right materials. The behavior of traveling long distances for nest materials have previously been observed by Potts (1985).

The increased distance traveled when caught in the thread algae habitat could also reflect a habitat shift. Skiftesvik (2015) found larger corkwing in more exposed areas. The observed increase in distance traveled might be that fishes move away from the thread algae habitat to kelp habitats in more exposed areas when reaching a suitable size.

4.3.2 Goldsinny

Goldsinny was also found to move significantly shorter on Saltkjerholmane than on Lambøya. Besides the fact that the two islands vary in size, the difference in movement on the two islands suggests that there could be other factors influences the observed movement such as differences in wrasse densities and/or habitat qualities.

There was a higher overall density of goldsinny on Lambøya throughout the project (Appendix; table 2). The higher density at Lambøya indicate that Lambøya overall is a better habitat for goldsinny while Saltkjerholmane is less so. With high densities the population will occupy a wider range as intrinsically poorer habitats are inhabited, because of density-induced declines in the quality of the habitat (Wootton 1998). This can result in the fish having to claim poorer territories and move further to get adequate nutrition. The low density on Saltkjerholmane while overall being a poorer habitat allow goldsinny to choose the absolute best territories, which likely provide sufficient resources in close proximity that will make long travels unnecessary. Saltkjerholmane has generally a gentler incline around the island with shallow sandy areas that stretch further from the shoreline than on Lambøya. Since a limiting factor for goldsinny distribution appear to be the presence of a shelter hole, cave or crevice (Sayer, Treasurer, and Costello 1996) the absence of rocky substrate would make Saltkjerholmane a overall poorer habitat for goldsinny.

The secondary model showed a small increase in distance traveled when longer time had passed since the last observation. Although this seems logical, goldsinny shows high site fidelity and return to the same territory over several seasons (Hilldén 1981; Sayer 1999). The majority of goldsinny moved very short distances between observations even after a long time had passed, but some few individuals moved very long distances compared to the other recaptured goldsinny. These long travels were mainly observed over the winter. Goldsinny seeks refuge and enter torpor, a dead-like stasis where oxygen uptake rates are reduced when temperatures are reduced below 5° C (Sayer and Davenport 1996). The observations that the goldsinny had moved far when a winter had passed may have been the result of their former habitat having been destroyed or occupied after returning from torpor, which resulted in a search for a new, suitable place to form a territory. The time when the fish becomes active will be determined by the local temperatures so goldsinny located in the areas where temperatures increase first will have the opportunity to be the first to find the best habitats.

4.3.3 Ballan wrasse

I found that of the 12 recaptured ballan wrasse, six individuals were between 376-425mm, and six individuals were between 114-173mm. Ballan is a monandric protogynous hermaphrodite where juveniles first mature as a females when approximately 160-180mm, and then change sex to male when reaching 340-400mm (Muncaster, Norberg, and Andersson 2013; Darwall et al. 1992). The home range of ballan is small and segregated by size, where smaller individuals are found to move longer than the highly territorial males (Villegas-Ríos, Alós, et al. 2013). By comparing the distance between these observed groups, it appears that the larger individuals who are likely to be territorial males, moved on average 77 meters between observations, while the smaller immature/female group moved on average 132 meters between observations, supporting the aforementioned.

4.4 Recapture probability

Analyzing the probability of being recaptured was mainly a tool for seeing whether the observed variation in intraspecific movement patterns correlated with the effects influencing recapture probability and whether there are any discrepancies in my previous results. The factors which effect the horizontal distance traveled for corkwing and goldsinny, should also affect the probability of being recaptured, since with increased distance traveled it is more likely that the encounter the barrier provided by the stationary fyke nets, and subsequently, increase the chance of being captured again. Because recapture probability is a way of detecting activity, it allowed me to see whether periods had an effect on the movement of corkwing and goldsinny. The seasonal variation is not clear in the measured distance traveled by the individuals, since the interval in which the fish moved could vary markedly in duration.

Corkwing

The recapture probability was higher on Lambøya and for bigger corkwing. This correlates with the observed intraspecific movement patterns of longer horizontal movement on Lambøya, and longer movement when bigger.

There was a higher probability of being recaptured in Period 2. Period 2 was during May 2018 and the mean temperature during this period was 10.5°C. Corkwing wrasse is temperature-sensitive, and activity is likely to decrease with lower temperatures (Deady and Fives 1995b; Thangstad 1999). The increase in recapture probability in Period 3 and 4 could therefore be related an increase in activity levels with the higher mean temperatures (14°C, 16.4°C). The highest increase in recapture probability occurred in Period 4. This could be related to the end of the spawning season when parental care is over, the fierce territorial behavior is relaxed, and increased movement associated with foraging ensue.

There was also a higher probability of being recaptured in habitat Type B. The dominant algae in this habitat was green sea finger. This small tree-like green algae, can be seen in figure 4. It might be that the dominance of this specific algae does not have the potential to support small home ranges due to a lack of recourses.

Goldsinny

Goldsinny was more likely to be recaptured in Period 2,3 and 4, unfortunately temperature data from Period 1 was not available. However, the somewhat similar probability of being captured during these periods show that goldsinny is less sensitive to temperature than corkwing and become active at lower temperatures(Darwall et al. 1992; Sayer, Gibson, and Atkinson 1993; Deady and Fives 1995b)

There was a higher probability of being recaptured in the thread algae habitat. The importance of algae in goldsinny habitats is somewhat unclear. Hilldén (1984) performed an experiment where he showed that when an area was cleared of algae, it was no longer supporting goldsinny territories. However, Collins (1996) found goldsinny territories in rocky areas with little to no algae. Goldsinny might be more reliant on the complex refuge provided by algae in shallower depths (Sayer, Gibson, and Atkinson 1993). One can argue that the thread algae habitats are less complex than the ones dominated by kelp and that subsequently the thread algae habitat may require larger individual territories and in turn more activity.

4.5 Potential Impacts of wrasse fisheries

The movement by the species of wrasse at the study location was local, and with little horizontal movement. The absence of movement between the islands indicates that dispersal of wrasse >10 cm over depths >20 meters is rare if it ever occurs. The observed avoidance of deep waters suggests that island populations of wrasse might be especially vulnerable to overexploitation from wrasse fisheries. As local recruitment and an eventual influx of fish-larvae/eggs from other localities could be the only source of recruits. Local environmental conditions affecting dispersal and settlement of fish larvae is likely to be a decisive factor for the recruitment potential of local island-populations of wrasse. Extra caution should be taken when harvesting wrasse from islands, as overexploitation might deplete populations that would find it difficult to recover.

The removal of wrasses from local ecosystems can possibly affect other species as well. The smaller wrasses are important prey for larger piscivores, and one of the most important food organisms for the Atlantic cod (Nedreaas et al. 2008). Though not often observed in the wild, cleaning behavior by temperate wrasse has, in all likelihood, also an impact on host fish (Henriques and Almada 1997).

Wrasses also have complex life histories and social structures. Large disruptions from harvesting may alter population structure in small populations (Darwall et al. 1992; Rowe and Hutchings 2003). I found during this thesis that the distance traveled and consequently, the capture probability of corkwing was higher with a larger body size. Corkwing displays sexual dimorphism, where nesting males grow faster and bigger than females and sneaker males (G. W. Potts 1974; K. T. Halvorsen et al. 2016). Being larger put them at higher risk of being caught since fisheries are more prone to target larger, faster-growing individuals, than smaller, slower-growing fishes (Rowe and Hutchings 2003). The removal of nesting males can cause a shift in the sex ratios of the population. The possibility of encountering suitable mates might decrease, effecting population productivity, and if the caring parent is removed harm offspring-survival and destabilize social structures (Rowe and Hutchings 2003; Sutter et al. 2012; Darwall et al. 1992).

5 Conclusion

According to my results, the horizontal movement was short, and there were no movements from one island to another made by any of the five wrasse species. Corkwing wrasse moved longer distances than goldsinny, and both these species moved shorter distances on the smaller island Saltkjerholmane. Corkwing moved longer when larger, and when first observed in habitats dominated by thread algae. Corkwing were more likely to be recaptured when there were higher temperatures in the water, if recaptured in a habitat dominated by green sea fingers (Codium), and after the spawning season. Goldsinny were more likely to be recaptured in thread algae habitats, and activity did not seem influenced by changes in temperature during the study. The observed movement patterns suggest that there is low recruitment in wrasse populations situated on islands, consequently caution should be taken when harvesting wrasse from islands to avoid overexploitation. The removal of wrasses from local ecosystems can possibly affect other piscivore populations, as wrasse is an important prey species. Movement patterns observed for corkwing wrasse make this species susceptible to sex-selective harvesting.

Measures such as maximum size limits should be taken in order to protect the large males of the temperate wrasses. And further research on wrasse movement should be carried out with different techniques such as acoustic and/or radio telemetry in order to get a more detailed understanding of the movement patterns of the five species of wrasse found along the Norwegian coast. This information may be crucial in order to develop a sustainable fishery for these species, without disrupting the population structures.

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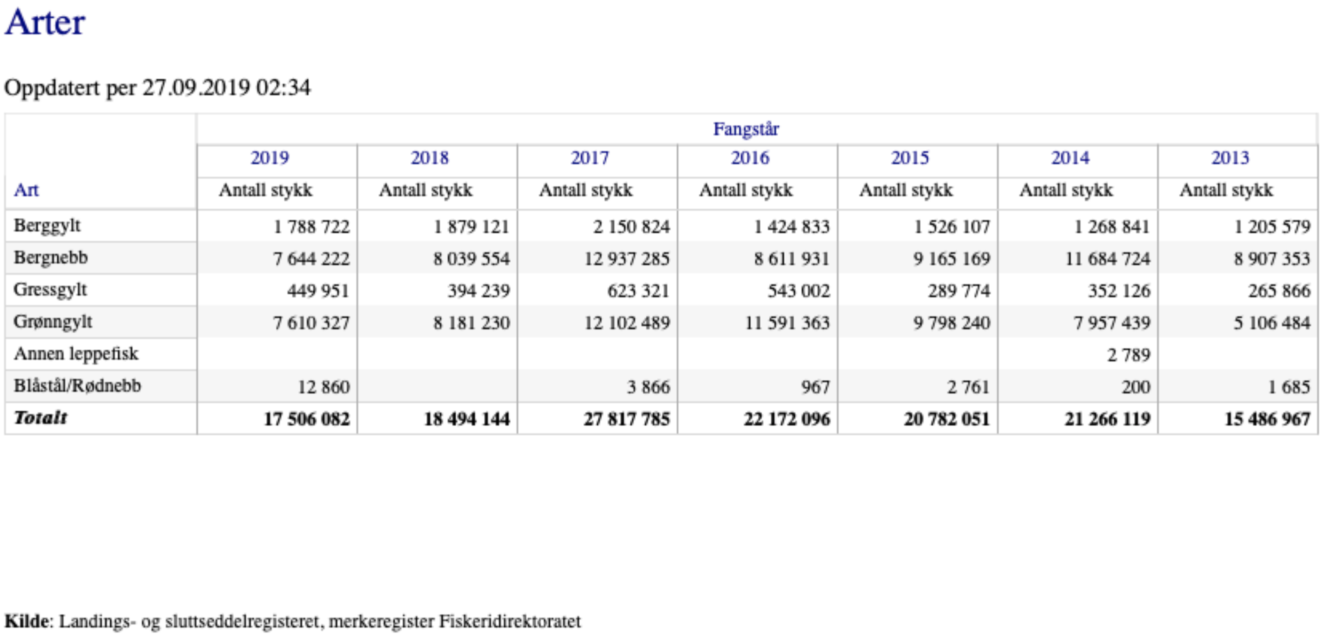
7 Appendix

Table 1: Reported landing of each species of wrasse in Norway during the last seven years. Bergylt = Ballan wrasse. Bergnebb = Goldsinny wrasse. Gressgylt = Rock cook. Grønngylt = Corkwing wrasse. Blåstål/Rødnebb = Cuckoo wrasse. Annen leppefisk = Other wrasse. (https://www.fiskeridir.no/Yrkesfiske/Tall-og-analyse/Fangst-og-kvoter/Fangst-av-leppefisk)



Arter

Oppdatert per 27.09.2019 02:34

	Fangstår						
	2019	2018	2017	2016	2015	2014	2013
Art	Antall stykk	Antall stykk	Antall stykk	Antall stykk	Antall stykk	Antall stykk	Antall stykk
Berggylt	1 788 722	1 879 121	2 150 824	1 424 833	1 526 107	1 268 841	1 205 579
Bergnebb	7 644 222	8 039 554	12 937 285	8 611 931	9 165 169	11 684 724	8 907 353
Gressgylt	449 951	394 239	623 321	543 002	289 774	352 126	265 866
Grønngylt	7 610 327	8 181 230	12 102 489	11 591 363	9 798 240	7 957 439	5 106 484
Annen leppefisk						2 789	
Blåstål/Rødnebb	12 860		3 866	967	2 761	200	1 685
Totalt	**17 506 082**	**18 494 144**	**27 817 785**	**22 172 096**	**20 782 051**	**21 266 119**	**15 486 967**

Kilde: Landings- og sluttseddelregisteret, merkeregister Fiskeridirektoratet

Table 2: The average catch per unit effort of corkwing and goldsinny on Lambøya and Saltkjerholmane over the duration of the project.

Species	Mean CPUE Lambøya	Mean CPUE Saltkjerholmane
Corkwing	15.14	17.73
Goldsinny	21.4	13.77

Figure 1: Map showing distance and depth between the three islands. The line between Lambøya and Bleikjo is 469.2 meters. The line between Bleikjo and Saltskjerholmane is 259.5 meters. (https://kart.fiskeridir.no/fiskeri)

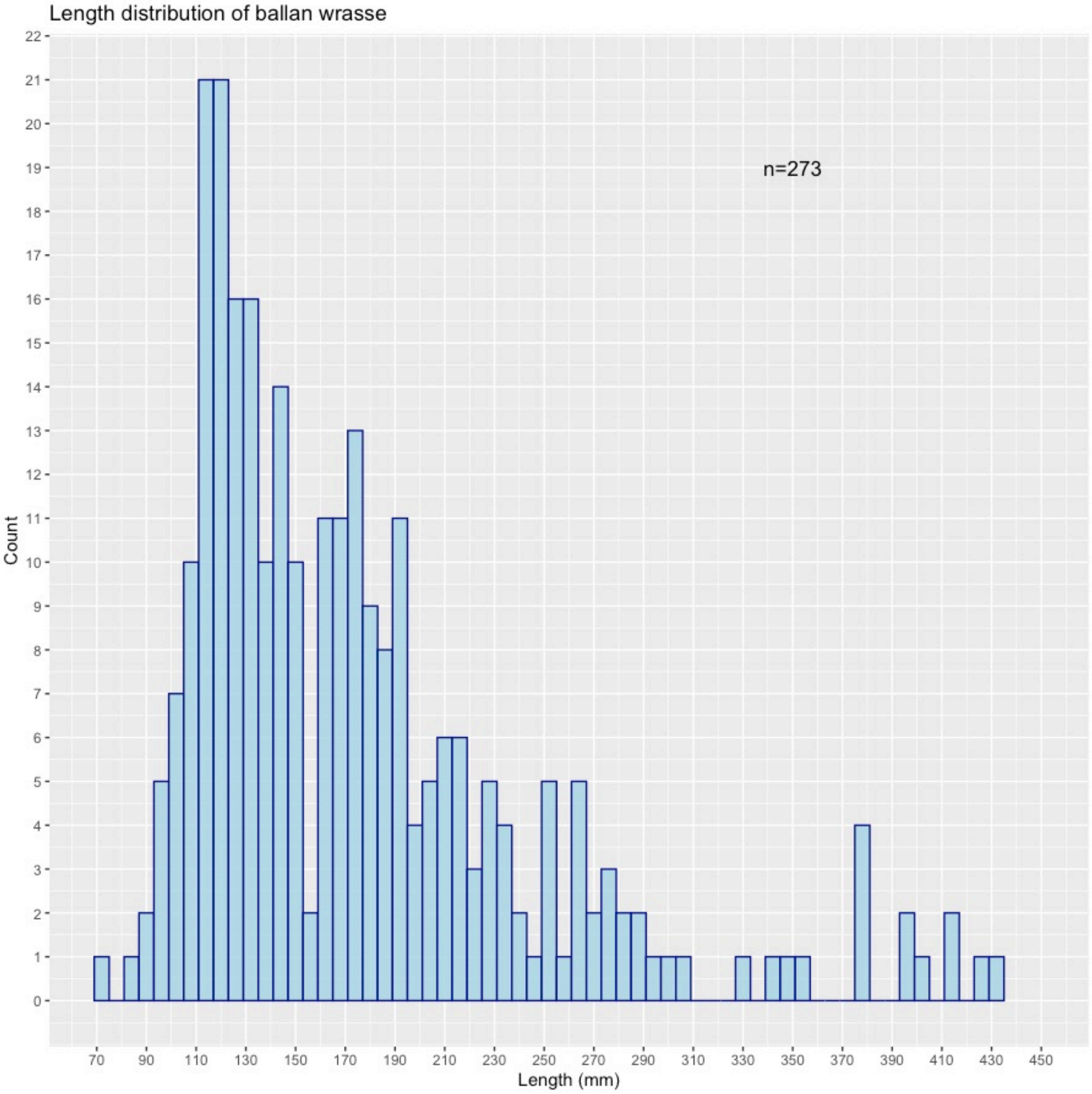


Figure 2: Length distribution of caught and measured ballan wrasse.

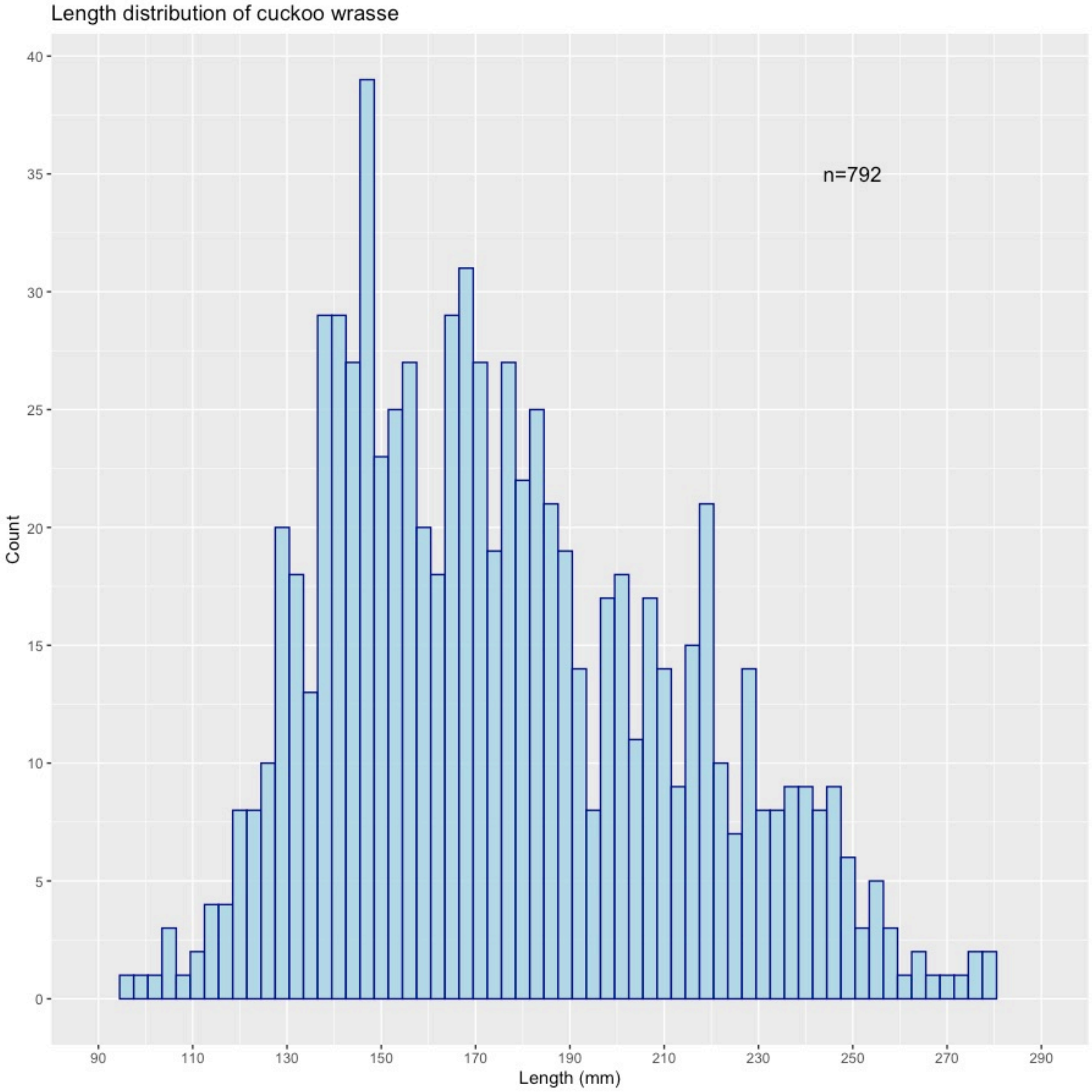


Figure 3: Length distribution of caught and measured cuckoo wrasse.

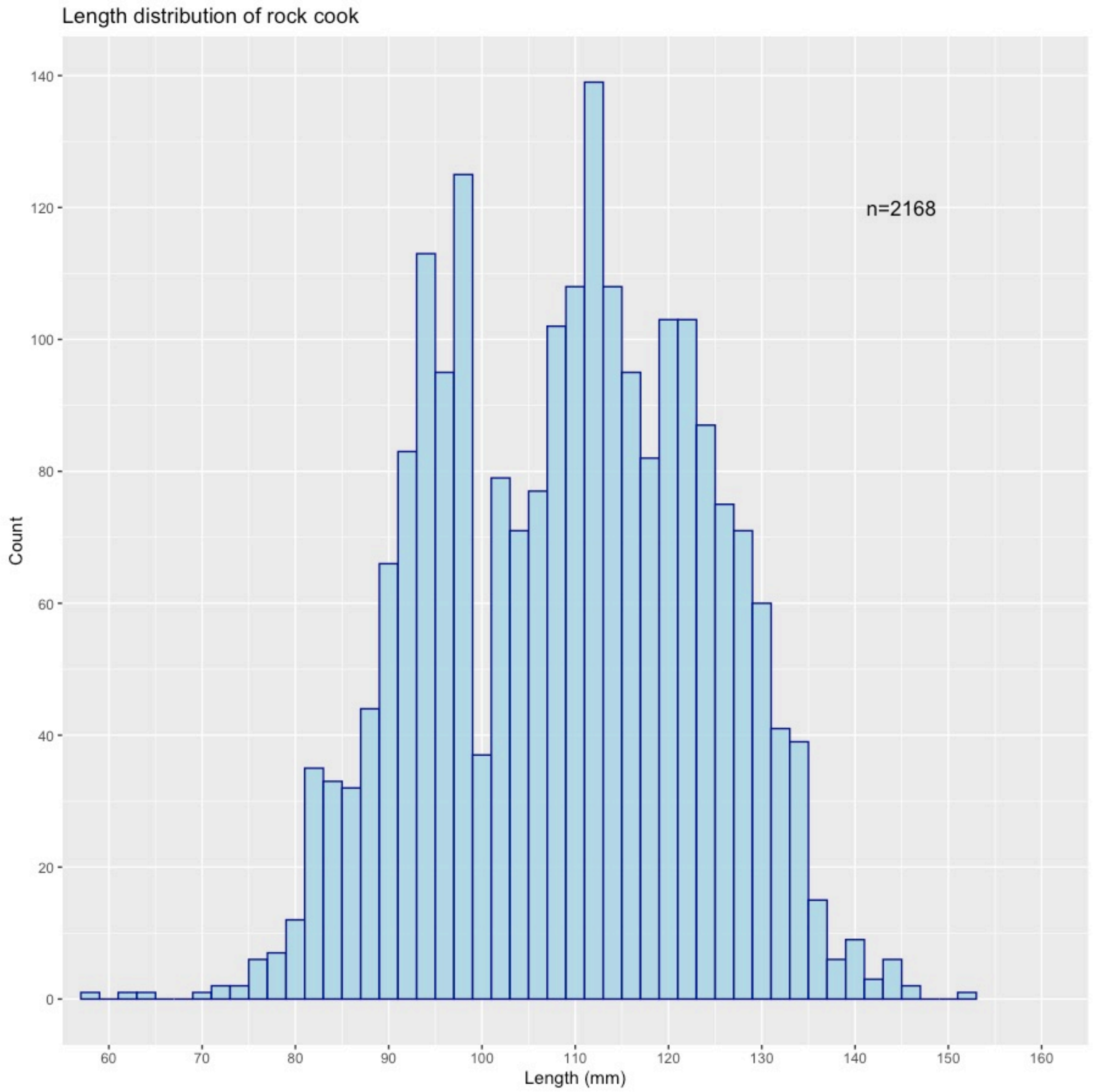


Figure 4: Length distribution of caught and measured rock cook.