ICES Journal of Marine Science Advance Access published November 21, 2014

ICES Journal of Marine Science

ICES CIEM International Council for the Exploration of the Sea Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science; doi:10.1093/icesjms/fsu211

Distribution and habitat preferences of five species of wrasse (Family Labridae) in a Norwegian fjord

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Skiftesvik, A. B., Durif, C. M. F., Bjelland, R. M., and Browman, H. I. Distribution and habitat preferences of five species of wrasse (Family Labridae) in a Norwegian fjord. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsu211.

Received 14 July 2014; revised 30 October 2014; accepted 30 October 2014.

Wrasse (Labridae) are used widely as cleaner fish to control sea lice infestation in commercial farming of Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) in Norway. As a result, there is an intense fishery for wrasse along the Norwegian coast. Little is known of the population ecology of wrasse and, therefore, an evaluation of their distribution, demographics, and habitat preferences was required as a baseline from which to assess the impact of the fishery. We analysed experimental catch data from a 3-year survey carried out in 1997–1999 (before the fishery began) during and after the wrasse spawning season in a Norwegian fjord. Corkwing wrasse (*Symphodus melops*) was always the most abundant species, ranging from 52 to 68% of the catches. Goldsinny (*Ctenolabrus rupestris*) and rock cook (*Centrolabrus exoletus*) were the second most abundant species (up to 30%). Ballan (*Labrus bergylta*) and cuckoo (*Labrus mixtus*) wrasse represented <2% of the catches. Rock cook was relatively more abundant at more exposed stations, while corkwing wrasse was characteristic of more sheltered stations. Goldsinny and ballan wrasse both occupied mainly intermediate stations in the more protected areas. Smaller fish were found at the most protected areas, while larger fish were found at the more exposed stations. Sex ratio in goldsinny and rock cook varied significantly from year to year. In corkwing, the sex ratio remained the same each year, and females were always in larger proportion (61–66%). Spawning occurred mainly in June for goldsinny, rock cook, and corkwing wrasse. The fact that species composition and/or size distributions vary considerably over very small distances must be considered in monitoring programmes. Erroneous conclusions about shifts in species composition can easily be made simply because sampling gear are set in slightly different areas.

Keywords: ballan, cleaner fish, corkwing, cuckoo, goldsinny, habitat use, multiple correspondence analysis, rock cook, sex ratio.

Introduction

Wrasse are a family of marine fish (Labridae) that are widely distributed along the coastal zones of the Indian, Pacific, and Atlantic oceans (Nelson, 1994; Helfman *et al.*, 2009). There are more than 500 species, the majority of which are brightly coloured reef dwellers. Wrasses are abundant in temperate coastal ecosystems and represent important predators that feed on a variety of invertebrates as well as being forage fish for other fish and birds (Helfman *et al.*, 2009). Some species have evolved cleaning symbioses with larger fish (e.g. Côté, 2000). This has led to wrasse being used as cleaner fish to control the copepod ectoparasite *Lepeophtheirus salmonis* (the salmon louse) by coculturing them with Atlantic salmon (*Salmo salar*, Linnaeus,1758) and rainbow trout (*Oncorhynchus mykiss*, Walbaum, 1792) on commercial farms (e.g. Bjordal, 1988, 1990, 1992; Costello and Bjordal, 1990; Treasurer, 1994a; Deady *et al.*, 1995; Kvenseth, 1996; Skiftesvik *et al.*, 2013; Leclercq *et al.*, 2014). Controlling salmon lice infestations is one of the greatest challenges to the sustainability and expansion of large-scale Atlantic salmon farming (Costello, 2009).

In 2008, salmon lice in several geographic areas developed resistance to the most commonly used chemotherapeutant (Slice™; Jones *et al.*, 2013), stimulating renewed interest in the use of wrasse as cleaner fish. Using cleaner fish to reduce parasite loads has obvious advantages over chemicals and pesticides. The result has been a dramatic increase in the fishery for wild wrasse. For example, the estimated use of wrasse in Norway surpassed 14 million fish in 2012, and it has developed into one of the most lucrative coastal fisheries (Norwegian Directorate of Fisheries statistics). Thus, there is growing concern that the fishing pressure on wrasse is unsustainable. Another concern is that the need for cleaner fish in the salmon industry coincides with the spawning season of wrasse. Species-specific variability in spawning and its temperature dependence are unknown. Moreover, the selective removal of individuals of the specific size needed for use as cleaner fish and the continuous intense fishing pressure in the same areas may alter the population structure (Darwall *et al.*, 1992; Varian *et al.*, 1996).

Four species of wrasse are used as cleaner fish for delousing salmonids in Norway (Kvenseth, 1996; Skiftesvik *et al.*, 2014a). Although they have been treated as a single species by the fishery, i.e. the generic "wrasse", they exhibit different life history strategies, necessitating different management and monitoring measures. Little is known of these four species: goldsinny wrasse (*Ctenolabrus rupestris*, Linnaeus, 1758), corkwing wrasse (*Symphodus melops*, Linnaeus, 1758), rockcook (*Centrolabrus exoletus*, Linnaeus, 1758), and ballan wrasse (*Labrus bergylta*, Ascanius, 1767). Therefore, a 3-year sampling programme was carried out in a Norwegian fjord, during and after the wrasse spawning season. The objective was to investigate the population dynamics, demographics, distribution, and habitat preferences of these species. This survey was conducted before the recent development of the wrasse fishery in this region; therefore, the data collected represent a baseline from which to assess the impact of the fishery on the wrasse population. We herein report on the overall spatial and temporal distribution of the targeted species in the study's geographic region.

Methods

Fish sampling

Sampling was conducted in late June, late July, and early September in 1997, 1998, and 1999 in the Lysefjord in southwestern Norway (Figure 1). During each sampling period, fykenets [colour = black; lead net length = 3.5 m; trap length = 2.5 m; mouth size = 45 cm in diameter; 4 × 45 cm diameter rings; mesh size (outermost chamber = 1.6 cm; all other chambers = 1.0 cm)] were set at 55 locations (hereafter referred to as stations), identified by marking prominent stones with numbers so that the fykenet locations would be identical every year. The 55 stations were grouped into three main areas with different degrees of exposure to the sea. Area 1 (25 stations) was sheltered and protected from wave action due to the peninsula located on the southwest side (Figure 1c). Area 2 (15 stations) was exposed to prevailing winds from the southwest and received the most waves as it was more open to the ocean (Figure 1d). Area 3 (15 stations) had the shallowest stations and intermediate wave exposure (Figure 1d). Area 1 displayed small rock substrate and macroalgae; Area 3 was characterized by sandy bottoms and large rocks along the edges. Finally, certain stations in Area 2 corresponded to relatively deep waters (ca. 40 m) and were characterized by kelp beds (Figure 1d).

The fykenets were attached on one end to the shore and then set perpendicular to the shoreline. Fish were removed from the fykenets without anaesthesia and measured for total body length. The sex of

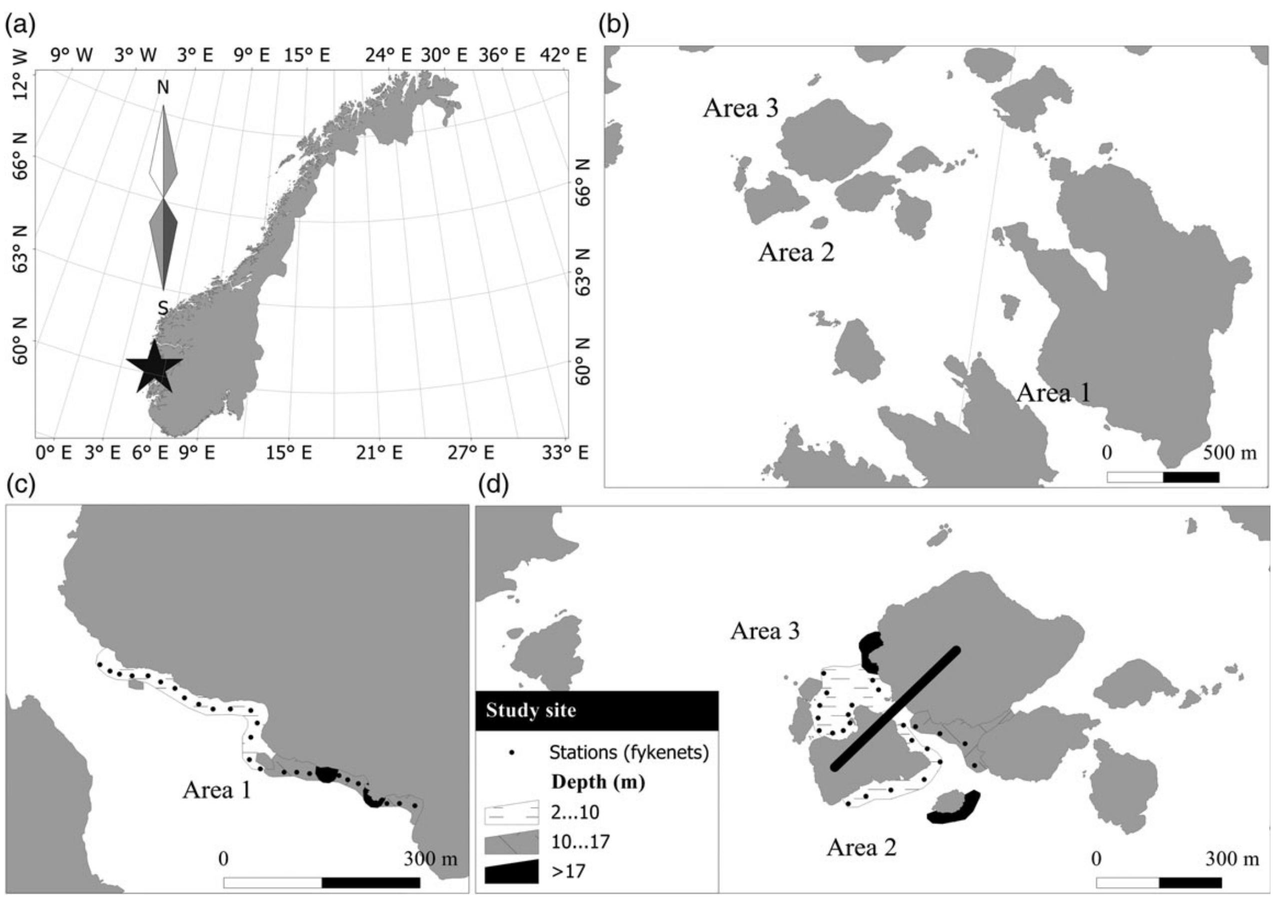

Figure 1. (a) Location of the study area (star symbol). (b) Map of the study area in the Lysefjord in southwestern Norway. (c) Detailed map of Area 1. Points mark the locations of fykenets (25). Areas are shaded according to their approximate depth. (d) Detailed map of Areas 2 (15 fykenet sets) and 3 (15 fykenet sets).

spawning individuals was determined by pressing the abdomen and inspecting milt or roe. Individuals from which no milt could be extruded were categorized as "sex unknown" and "not spawning".

Water temperature at 5 m depth was measured every day at the Institute of Marine Research's Austevoll Research Station, 15 km from the sampling sites (Table 1).

In accordance with the Norwegian Animal Welfare Act (LOV 2009-06-19 nr 97: Lov om dyrevelferd), no permit was required to handle fish in the manner required by this field study. All sampling was conducted to minimize stress and damage to the animal, and fish were released after being measured.

Data analysis

Species composition in the different areas was investigated using correspondence analysis (CA; Benzécri, 1973; Lebart *et al.*, 1995). This exploratory technique analyses two-way tables containing some measure of correspondence between qualitative variables. In this case, the variables were species and stations. The advantage of this approach is that it will detect even non-linear relationships, since χ^2 distances are computed to detect similarities. Row (stations) and column (species) scores can then be plotted on the same factorial axes. Hence, stations that have similar species composition will have similar factorial scores. Here, factorial scores were assigned symbols, and stations were plotted on a map. Thus, stations with the same symbol had similar species composition. Species were presented with the corresponding symbol in a factorial plot.

Multiple correspondence analysis (MCA) is an extension of CA to more than two variables (Volle, 1985; Escofier and Pagès, 1998) and is used to analyse a population of *N* individuals characterized by *J* qualitative variables. MCA allows quantitative and qualitative variables to be combined in the same analysis. Just like in CA, by transforming quantitative variables into qualitative variables, it becomes possible to observe non-linear relationships between variables (e.g. between spatial distribution and body length of fish). Here, MCAs were carried out on separate datasets for each species for which there were sufficient data (corkwing, goldsinny, and rock cook). Qualitative variables were: fish body lengths (sorted into 1-cm size classes), stations, and sampling year (1997–1999).

Table 1. Average monthly water temperature (°C) measured at 5 m depth at the Institute of Marine Research's Austevoll Research Station (60°5′42″N 5°13′8″E).

Month	1997	1998	1999
June	13.9	12	11.9
July	17.4	14	15
August	19.6	14.4	14.5
September	15.8	13.9	14

As for CA, row scores (stations) were assigned symbols and plotted on the first factorial axis of maps representing the sampling area, while species, length classes, and sampling years were presented in a factorial plot.

In multivariate analyses, inertia is a measure of dispersion of the multidimensional scatterplot (equivalent to variance). The percentage of total inertia explained by each factorial axis is given for the CA only. In MCA, these values are very low due to the nature of the calculation and will have little influence on the significance of the analysis (Escofier and Pagès, 1998).

χ^2 tests were carried out to determine whether species composition was statistically different between years. Kruskal–Wallis' analysis of variance was applied on fish lengths to assess statistical differences between years within each species.

Results

A total of 14 384 wrasse belonging to five species: corkwing, ballan, goldsinny, rockcook, and cuckoo wrasse (*Labrus mixtus*, Linnaeus, 1758), were collected.

Relative abundance and spatial distribution of wrasse species

The relative proportions of species varied significantly from year to year (χ^2 test, $\chi^2 = 402$, $p < 0.001$); however, corkwing wrasse was always the most abundant species, ranging from 52 to 68% of the total wrasse catches over the 3 years of the study. Goldsinny and rock cook were the second most abundant species (up to 30%). Ballan and cuckoo wrasse represented <2% of the catches (Table 2).

The four most abundant wrasse species occupied different areas (Figure 2). Rock cook was caught at the most exposed stations in Area 2 (Figure 2a and b); ballan and goldsinny wrasse were mostly found in Area 3 (shallow stations; intermediate wave exposure; sandy bottom with large stones along the edges). Finally, corkwing were more abundant in the sheltered Area 1 (Figure 2a). Cuckoo wrasse were examined separately because of their very low abundance relative to the other species. This species was present at every station and did not show any specific clustering.

Size of fish and location

Within each species, wrasse of similar sizes occupied similar areas. This was true for all three species: goldsinny, corkwing, and rock cook (Figures 3–5). In the MCA, smaller fish generally obtained positive factorial scores, and larger fish negative factorial scores (Figures 3a, 4a, and 5a). Spatially, almost all sheltered stations, most of which were located in Area 1, had positive scores (Figures 3b and c, 4b and c, and 5b and c), while more exposed stations had negative scores. Therefore, both the degree of exposure to oceanic conditions and the size distribution of the fish were reflected in factorial scores (F1). The factorial plots and the maps showed that

Table 2. Abundance of cuckoo wrasse (*L. mixtus*), ballan wrasse, (*L. bergylta*), goldsinny wrasse (*C. rupestris*), rock cook wrasse (*C. exoletus*), and corkwing wrasse (*S. melops*) collected with fykenets during three spawning seasons in the Lysefjord area, Norway.

Year	1997			1998			1999		
Sampling	June	July	August	June	July	August	June	July	August
Cuckoo	12	9	15	3	4	2	8	31	29
Ballan	68	24	28	25	31	14	23	28	17
Goldsinny	303	513	525	225	185	136	341	481	539
Rock cook	485	184	22	505	69	4	442	401	28
Corkwing	882	861	645	915	892	980	1402	1244	814

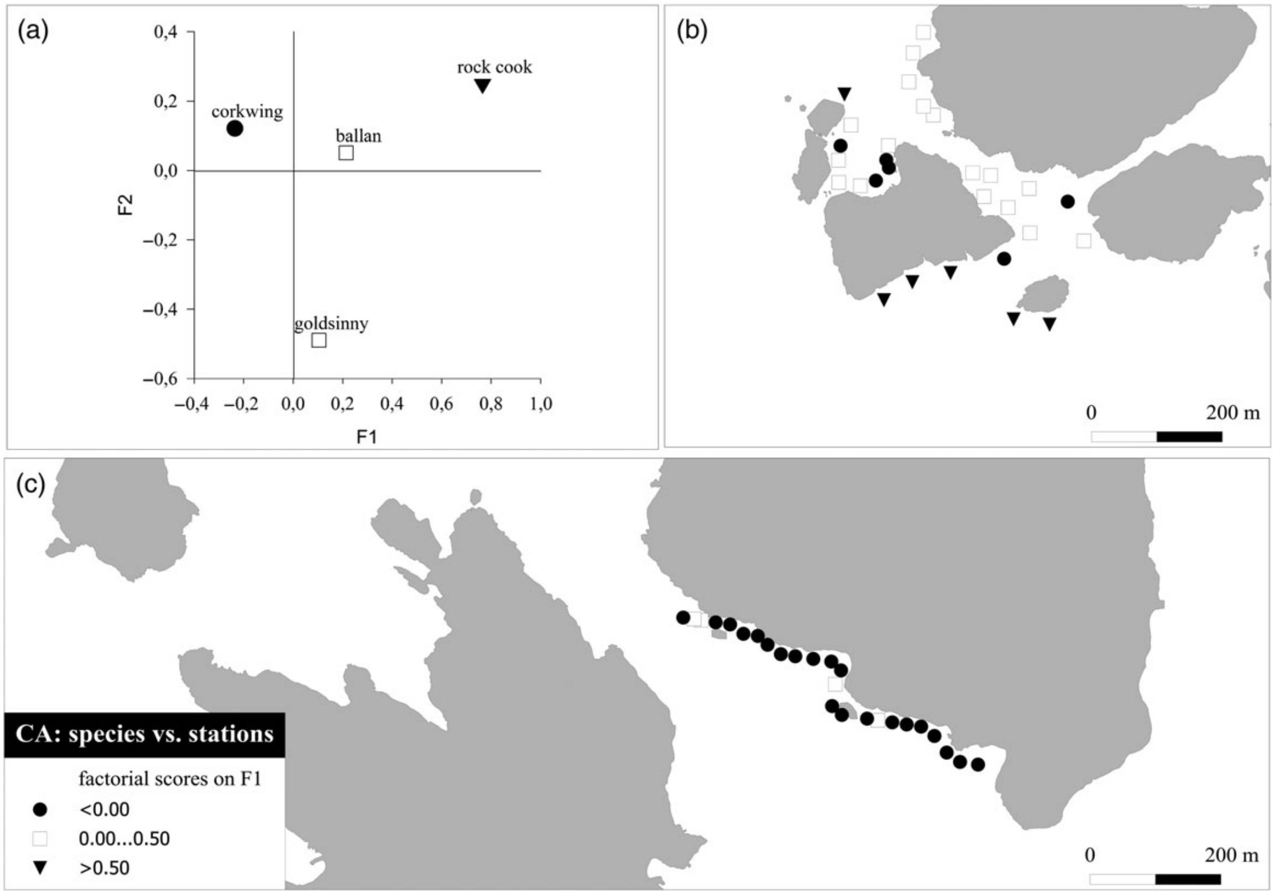

Figure 2. Spatial distribution of the four most abundant wrasse species: ballan wrasse (*L. bergylta*), goldsinny wrasse (*C. rupestris*), rock cook wrasse (*C. exoletus*), and corkwing wrasse (*S. melops*) collected in the Lysefjord area, Norway, during the spawning season in 1997, 1998, and 1999. Factorial scores were calculated using CA (stations vs. species) and assigned symbols based on their value: circle <0, squares 0–0.5, triangle >0.5. (a) Coordinates of species on the first two factorial axes (F1, F2), representing, respectively, 61 and 27% of the total inertia. (b and c) Factorial scores of stations (F1) represented on a map of the study area and assigned identical symbols as those used for the species.

the smaller fish occurred mainly in sheltered areas, while the larger fish occupied the more exposed areas. More specifically, goldsinny, rock cook, and corkwing that were below the mean size of the sample (respectively, 11, 10.5, and 12 cm; Table 3) were only found at Area 1. The projections of years on the factorial plots showed that the smaller size classes of goldsinny and rock cook were present mainly in 1999. The larger individuals of these two species were significantly more abundant in 1997 and 1998 (goldsinny: $H_2 = 199$, $p < 0.001$; rock cook: $H_2 = 159$, $p < 0.001$). Large corkwing were more abundant in 1997, while smaller individuals dominated in 1998 and 1999 ($H_2 = 311$, $p < 0.001$).

Sex ratios

Sex ratio in goldsinny and rock cook varied significantly from year to year (χ^2 test, goldsinny: $\chi^2 = 6.55$, $p = 0.038$; rock cook: $\chi^2 = 57.48$, $p < 0.001$). It was in favour of males in 1997 for goldsinny (56%), while slightly in favour of females in 1998 and 1999 (respectively, 53 and 51%). In rock cook, sex ratio was in favour of males (57–58%), except in 1997 (38%). In corkwing, the sex ratio remained the same from year to year (χ^2 test, $\chi^2 = 4.833$, $p = 0.089$), and females were always in larger proportion (61–66%). There were no differences in the spatial distribution of the sexes. For ballan and cuckoo wrasse, gender could not be determined on enough individuals to draw any conclusions.

Spawning season

In June, almost all goldsinny and rock cook were spawning (83 and 87%, respectively). The proportions of spawners dropped in July, especially for goldsinny (Figure 6). A high percentage of rock cook were still spawning in July (49% on average). The proportion of spawning corkwing wrasse in June was slightly lower (57%) than for the two other species and decreased to 15% in July. During that month, and for these three species, higher spawner percentages were found in 1997 than in the other 2 years. Very few spawning ballan wrasse were found (6% on average); the highest was 13% in 1997.

Discussion

Spatial patterns in the distribution of the different species of wrasse were described in an area now heavily fished for cleaner fish to be used on Atlantic salmon farms. These spatial patterns appeared stable, at least within the study period of 3 years. Since the collections were made before the fishery began, these data will serve as a baseline against which to compare data collected from future monitoring of these species.

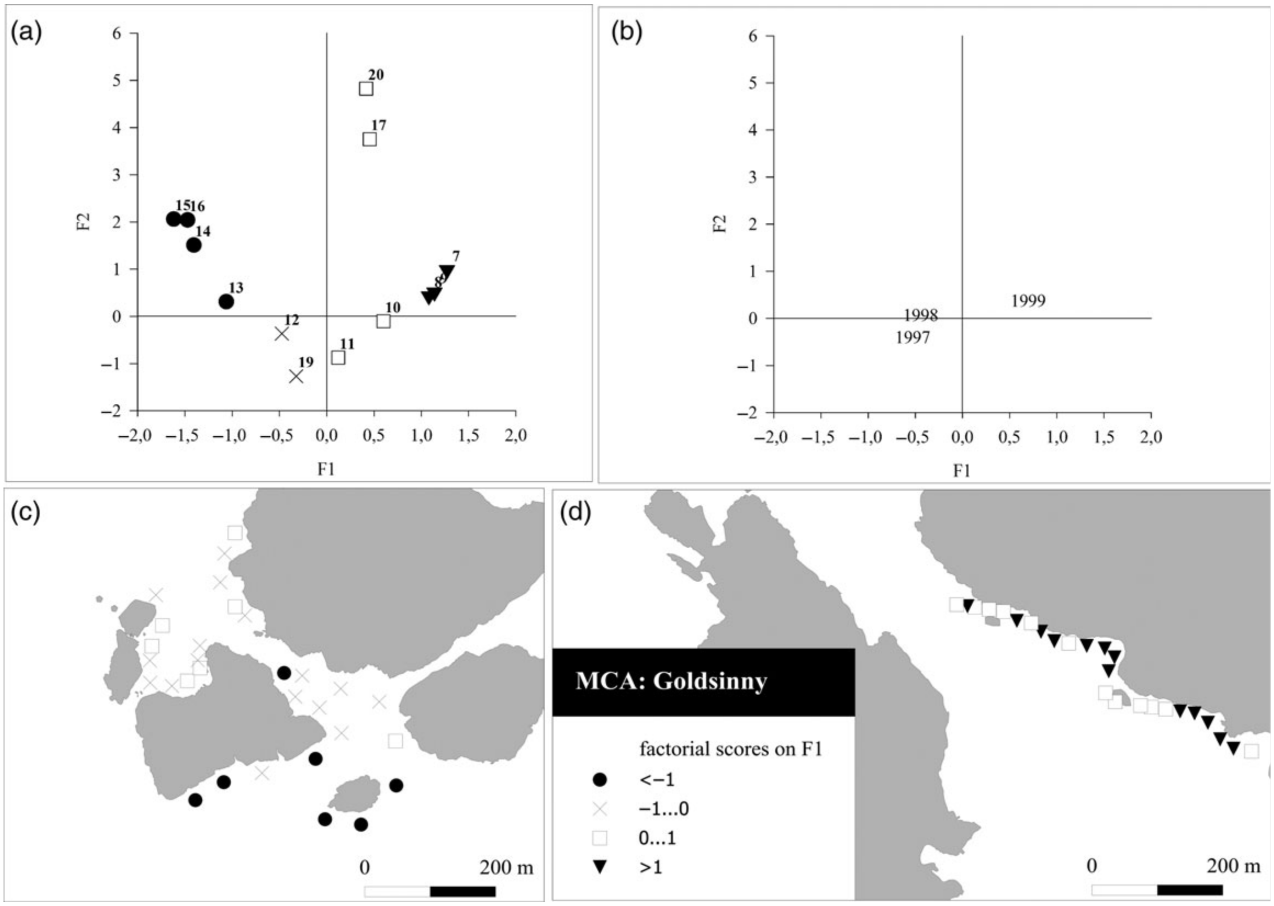

Figure 3. Size distribution of goldsinny wrasse (*C. rupestris*) collected in the Lysefjord area, Norway, during the spawning season in 1997, 1998, and 1999. Factorial scores were calculated using MCA (stations vs. length class vs. year) and assigned symbols based on their value: circle less than −1, cross −1 to 0, squares 0–1, and triangle >1. (a) Factorial scores of length classes of goldsinny plotted on the first two factorial axes (F1, F2). (b) Factorial scores of sampling years. (c and d) Factorial scores of stations (F1) represented on a map of the study area and assigned identical symbols as those used for the species.

Habitat preferences according to species and body size

The habitat preferences of wrasse are poorly documented. The temperate wrasse species reported on in this study showed species-specific spatial structure over a relatively small spatial scale. There was little variation over years, but high variation over short distances, with differences in species composition over distances of just a few metres. Individuals were segregated according to species and body size. This is consistent with earlier observations on the home range size of ballan wrasse (*L. bergylta*; Villegas-Rios *et al.*, 2013).

Goldsinny are typically found on rocky shores, in the intertidal zone, and down to depths of 50 m (Quignard and Pras, 1986; Sayer *et al.*, 1996a). High densities of goldsinny occur in areas exhibiting turbulent water movement (Hillden, 1978; Sayer *et al.*, 1993; Gjøsæter, 2002; this study). *In situ* observations by divers revealed that individuals can maintain position in fast moving water (Sayer *et al.*, 1993). Suitable refuge seems to be the factor limiting goldsinny distribution (Sayer *et al.*, 1993), as this species remains in refugia for long periods (Sayer, 1999). In contrast, corkwing prefer shallow protected areas (this study). They are usually present at depths <5 m (Quignard and Pras, 1986). In labrid species, body size is important in structuring spatial distribution because some species and/or sizes of fish may be unable to maintain station in locations with high wave energy or flow (Bellwood *et al.*, 2002; Fulton and Bellwood, 2004); large fish can access wave-exposed habitats (Nunes *et al.*, 2013). In our study, the smaller fish of each species (<11 cm) were always located in the more sheltered areas, while the larger fish were found in the more exposed areas. This indicates that these fish changed territories as they got larger. It is likely that beyond a certain size, the fish were able to forage in more exposed territory.

The spatial segregation of corkwing, goldsinny, and rock cook was not due to species-specific differences in size since there was overlap in the frequency distributions of their body lengths (from 6 to >20 cm). The degree of wave exposure may affect the distribution of fish in ways other than swimming ability and body form, e.g. via food availability, because invertebrate communities are different depending on wave energy (Leigh *et al.*, 1987) or via availability of shelter, because algal cover will vary with wave energy (Leigh *et al.*, 1987; Gaylord *et al.*, 1994). Water circulation will affect the assemblage of sessile species in a particular area, particularly filter and suspension feeders (Koehl, 1984). Waves may break or displace small mobile predators and herbivores, such as gastropods (Denny, 1985). Barnacles and mussels would be found in more exposed areas where they are strongly attached to the substrate.

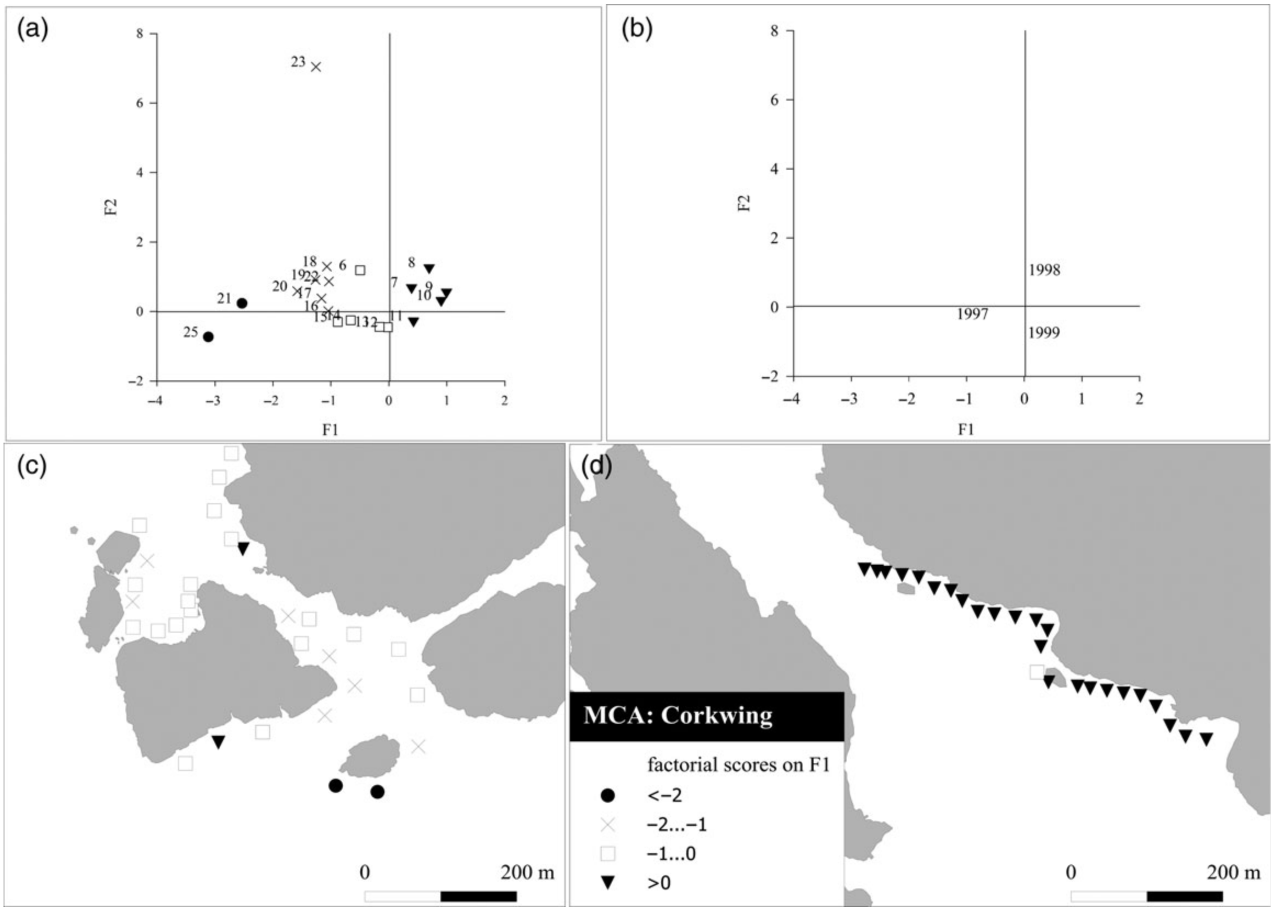

Figure 4. Size distribution of corkwing wrasse (*S. melops*) collected in the Lysefjord area, Norway, during the spawning season in 1997, 1998, and 1999. Factorial scores were calculated using MCA (stations vs. length class vs. year) and assigned symbols based on their value: circle less than −2, cross −1 to −2, square 0 to −1, and triangle >0. (a) Factorial scores of length classes of goldsinny plotted on the first two factorial axes (F1, F2). (b) Factorial scores of sampling years. (c and d) Factorial scores of stations (F1) represented on a map of the study area and assigned identical symbols as those used for the species.

Wrasse have a very diverse diet, and all species display the same feeding behaviour, which consists of pecking at slow-moving or sessile prey (Sayer *et al.*, 1995, 1996b). Corkwing diet is sometimes dominated by gastropod molluscs (Sayer *et al.*, 1996b), while mussels and barnacles are the dominant food items for goldsinny and larger corkwing (Deady and Fives, 1995; Sayer *et al.*, 1995). Although we did not look at stomach contents, these observations are consistent with the spatial dichotomy observed between goldsinny (exposed areas) and corkwing (sheltered areas). Although there are obvious disadvantages to inhabiting an area exposed to strong wave action, such areas often exhibit higher productivity because wave energy introduces more nutrients into the water column through increased hydrodynamics and an increased use of sunlight by algae (Leigh *et al.*, 1987; Gaylord *et al.*, 1994). In addition, since corkwing and the smaller individuals of the other wrasse species are not present in these areas, intra- and interspecific competition may be reduced.

How fishing gear might affect species diversity in the catch is unclear. One study reported that there was no species-specificity between different fishing methods (traps and fykenets; Treasurer, 1994b). In another study, goldsinnny sometimes dominated fykenet catches (Treasurer, 1996), while according to Skiftesvik *et al.* (2014b), corkwing wrasse were slightly more abundant in fykenets vs. traps. In any case, we used the same gear and sampling protocol throughout this study, so there should not be any gear effect on the results.

Sex-dependent spatial distribution

The sex ratios observed in our survey are consistent with those reported earlier for unfished populations of these species of wrasse (goldsinny, Sayer *et al.*, 1995; goldsinny and rock cook, Treasurer, 1994b).

Many wrasse species spawn and forage in territories maintained by the dominant males in the population (Sjölander *et al.*, 1972; Hillden, 1981; Potts, 1985). Corkwing males are especially territorial during spawning season and were found in lower proportions relative to females in our survey. They attract females into their nest and chase away other males. It follows that larger males would be more successful than smaller individuals. A change in the sex ratio due to the wrasse fishery targeting larger fish may destabilize social structures in dominant vs. subordinate males (Darwall *et al.*, 1992; Skiftesvik *et al.*, 2014a). This is a testable hypothesis that we will assess in future work.

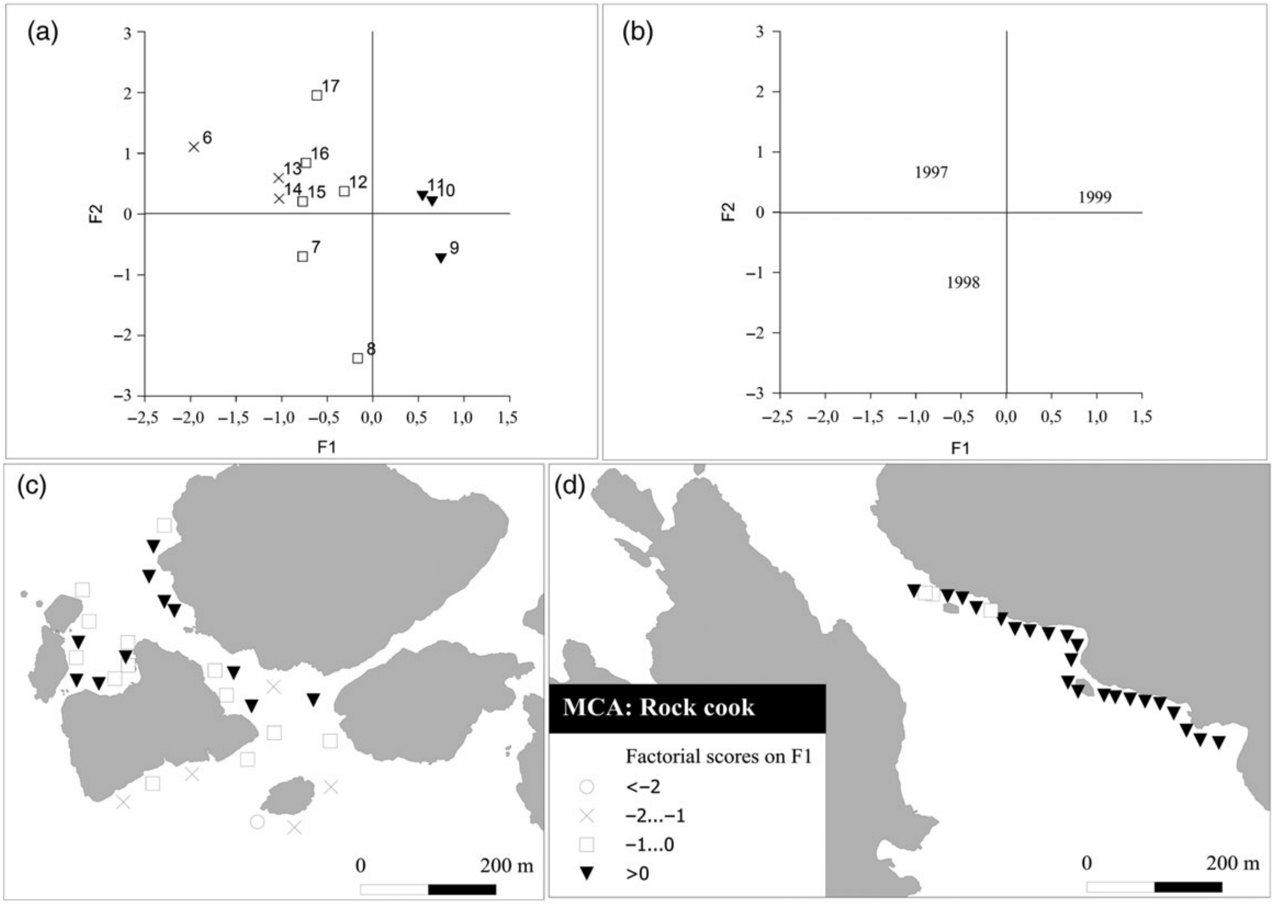

Figure 5. Size distribution of rock cook wrasse (*C. exoletus*) collected in the Lysefjord area, Norway, during the spawning season in 1997, 1998, and 1999. Factorial scores were calculated using MCA (stations vs. length class vs. year) and assigned symbols based on their value: cross greater than −1, squares 0 to −1, triangle >0. (a) Factorial scores of length classes of goldsinny plotted on the first two factorial axes (F1, F2). (b) Factorial scores of sampling years. (c and d) Factorial scores of stations (F1) represented on a map of the study area and assigned identical symbols as those used for the species.

Table 3. Body lengths of cuckoo wrasse (*L. mixtus*), ballan wrasse, (*L. bergylta*), goldsinny wrasse (*C. rupestris*), rock cook wrasse (*C. exoletus*), and corkwing wrasse (*S. melops*) collected with fykenets during three spawning seasons (1997–1999) in the Lysefjord area, Norway.

Species	Min–max (cm)	Mean (cm)	s.d. (cm)
Cuckoo	8.5–26	18	4
Ballan	4–39.5	18	6.5
Goldsinny	6.5–20.5	11	2
Rock cook	6–19	10.5	2
Corkwing	6–25	12	2.5

Goldsinny have smaller territories than corkwing (Hillden, 1981). This is consistent with our observation of proportionally fewer males for corkwing (38%) than goldsinny (52%), since larger territories would imply fewer males. A similar sex ratio in favour of females (68%) has been reported for this species (Sayer *et al.*, 1996b).

Spawning season

Almost all goldsinny and rock cook (>80%) were spawning in June. In another study, Skiftesvik *et al.* (1996) collected gravid female and running male rock cook, corkwing, and goldsinny in June. Although a considerable proportion (50%) of corkwing was still mature in June, peak spawning may have occurred earlier. Less than 20% of the ballan wrasse were spawning during this survey, probably because spawning had taken place earlier in the season. This is consistent with previous observations that spawning in ballan wrasse occurred in May–June in this area (Muncaster *et al.*, 2010). It seems that, at least in goldsinny, the number of fish that are actively spawning is highly seasonal (Sayer *et al.*, 1993). Outside of the spawning season, the fish remain inactive and hidden within refuges (Darwall *et al.*, 1992). Fishing for wrasse during the spawning season can induce massive mortality, especially in corkwing females (Skiftesvik *et al.*, 2014a). Therefore, understanding the environmental drivers of reproduction to be able to predict the spawning period for the different wrasse species is crucial in developing a well-informed management plan for the fishery.

Conclusions

The fact that species composition and/or size distributions vary considerably over very small distances is important to take into account in current monitoring programmes. For example, erroneous conclusions about shifts in species composition can easily be made simply because sampling gear are set in slightly different

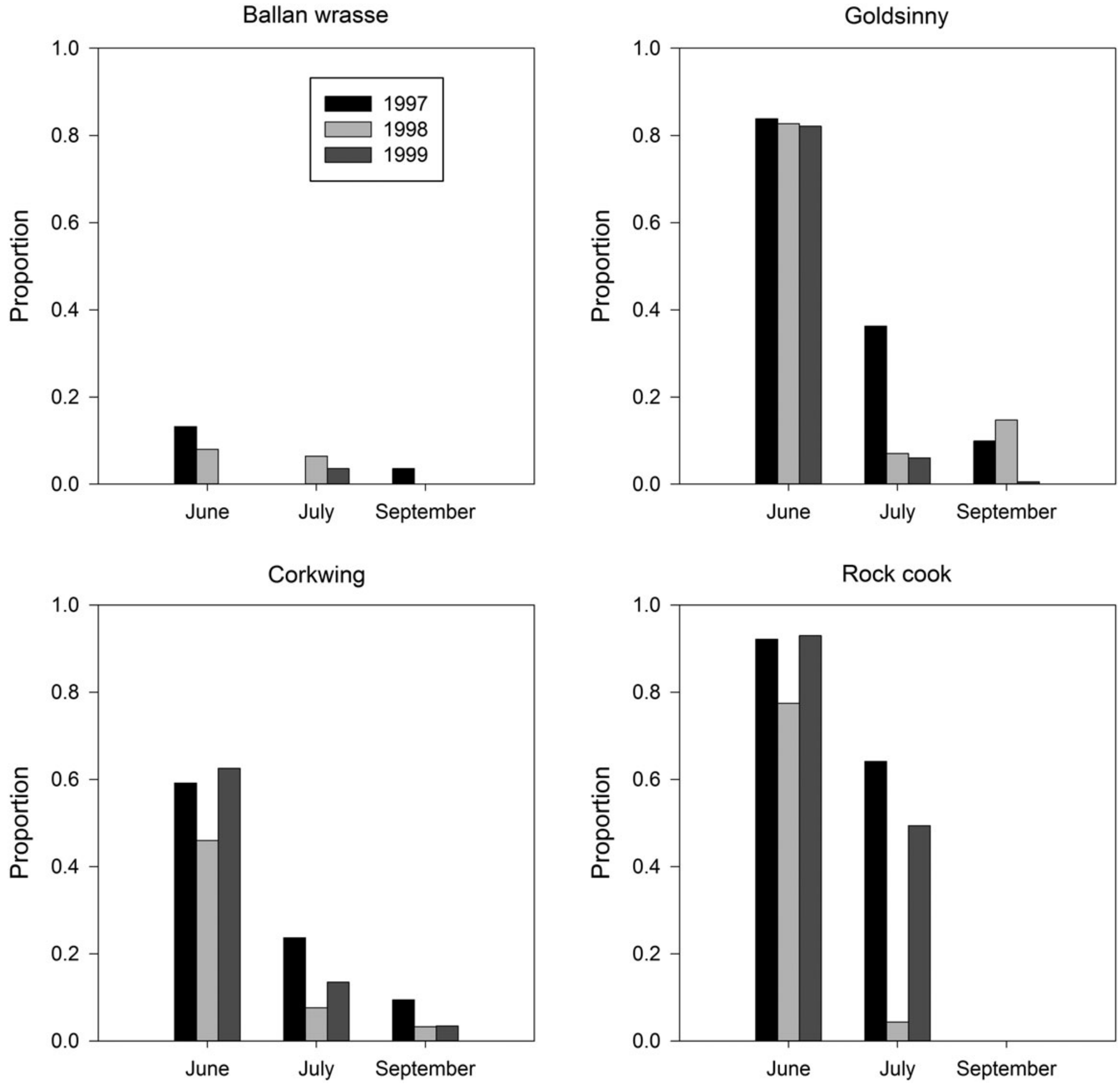

Figure 6. Maturation status of four species of wrasse, ballan wrasse (*L. bergylta*), goldsinny wrasse (*C. rupestris*), corkwing wrasse (*S. melops*), and rock cook wrasse (*C. exoletus*), collected in the Lysefjord area, Norway, during three spawning seasons. Bars represent the proportion of spawning fish assessed by pressing the abdomen and inspecting milt or roe.

areas. This is also supported by the very small ranges reported for ballan wrasse (Villegas-Rios *et al.*, 2013). In the present study, goldsinny exhibited a higher tolerance to wave energy, and is, therefore, able to colonize a wider range of habitats. Given this greater plasticity in access to different habitats, this species might have a better chance of recovering/sustaining an intensive fishery. In this sense, the ratio of corkwing to goldsinny might prove to be a valuable index for monitoring the effect of the fishery. Although corkwing was by far the most abundant species (up to 68%), this proportion may decrease in the future, especially if the fishery alters their natural social structure by selectively removing larger individuals.

The survey reported here is being expanded to assess the relative abundance and growth trajectories of these five species of wrasse throughout their distributional range along the Norwegian coast. Local site fidelity will also be investigated by mark–recapture of individually tagged fish.

Acknowledgements

This research was supported by the Research Council of Norway (Project 114081/122 to ABS) and by the Norwegian Institute of Marine Research.

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Handling editor: Emory Anderson