ICES CM 2000/N:31 Theme Session on Spatial and Temporal Patterns in Recruitment Processes

Factors affecting the distribution of wrasses (Pisces: Labridae) in a fjord system: analysis by generalised linear models

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Background

Generalised linear models (GLMs, see McCullagh & Nelder 1989) form a modern, flexible and unified approach to statistical modelling. GLMs are of particular value to the analysis of data from ecological surveys, because they allow for deviation from the assumption of normality in the models. Thus one may for instance fit models with Poisson or negative binomial (negbin) error terms and logarithmic link functions. The negbin distribution in particular is frequently applied in ecology, and often gives a good approximation to typically skewed catch data (high proportion of zero catch values, low means). Many of today's statistical computer packages (e.g. S-Plus) have inbuilt options for GLMs.

We used GLMs to study the spatial and temporal distribution of three common European wrasse species (Family Labridae) in relation to environmental variables from typical fjord habitats of western Norway. Goldsinny (*Ctenolabrus rupestris* L.), rock cook (*Centrolabrus exoletus* L.) and corkwing wrasse (*Symphodus melops* L.) are all described as facultative cleaner-fish, and have during the last decade been increasingly exploited as delousers in salmon pens in Norway and other countries. The general lack of knowledge about labrid ecology, coupled with concern about the growing fishery for cleaner-wrasse, makes this family of fishes an interesting objective for ecological research.

Materials and methods

Wrasse catch data were for the present study obtained from the Masfjord "cod enhancement" sampling project (1985-92; details in Smedstad et *al.* 1994). For a part of this project a 4 by 40 m beach seine was used, with which monthly samples (July 1986 through August 1990, $n = 174$) were collected to depths of 5-10 m on ten sampling sites in Masfjord and parts of adjacent Fensfjord (Figure 1).

Masfjord and Fensfjord are typical fjords of the western region of Norway. Masfjord has a deep (>500 m) middle region (subarea 2, Figure 1) and a shallow (75 m) sill, formed by ice age glacier erosion. The shoreline is generally steep and rocky, and is enclosed by high mountains. The outer archipelago into Fensfjord (subarea 3) is shallower (< 200 m), with numerous small islands and sandy or muddy bays with tufts of eelgrass. The upper fjord littoral is mostly covered with fucoid weeds, while sublittorally patches or forests of *Laminaria*-kelps can be found. Constant freshwater runoff from the hydroelectric power plant at the head of the fjord (subarea 1) creates a permanent 1-3 m brackish water layer, which in turn gives mostly ice-free conditions during winter Temperatures here vary from 2-

5°C in the winter to 12-17°C In the summer, In the intermediate zone below salinity fluctuates around 34, with temperatures from 7 to 15°C; hydrographical conditions here are very dynamic, with rapid water exchanges through coastal currents.

From transect diving (scuba) on each sampling site the following habitat characteristics were recorded angle of the substratum, substratum type (soft bottom, rubble, or broken or smooth rock), degree of algal (macrophyte) cover, and degree of exposure to waves. Three to four ordinal levels were used to describe each variable (e.g. [I] absent, [2] patchy, [3] medium, [4] abundant) Temperature (“C) and salinity (S) were measured as part of the sampiing procedure. Based on habitat characteristics, each site could be classified as either steep, weedy “rocky shore” habitat or shallow, sparsely vegetated *“mudflat”* habitat. Measured variables were fitted as factors to generalised linear ANOVA or regressron models with negbin error terms, using the forward selection technique.

Results and discussion

All three species were abundantly present on the sampling locations, with goldsinny numerically dominant (55% of total catch, Table 1). Up to 84 % of all sampled individuals were O-group < 5 cm, larger (I+) fish often being more mobile and able to escape the advancing seine netting The catch-frequency distributions of juveniles and adults alike were highly aggregated * especially for the school forming rock cook -, indicated by low values of the negbin shape or dispersion parameter *k* Although negbin goodness-of-fit to the catch data could not In all cases be assessed (Table I), low mean catch rates, high variance-to-mean ratios (2-12), and k’s much less than one (0 OS-0.22) suggest a good negbin approximation to the observed catch-frequency distributions.

Abundance was highly dependent *on* season and water temperature, all species being most active and available to capture May through August (Figure 2). Studies have shown that wrasses assume a state of inactivity or torpor at low (< 5°C) winter temperatures (Sayer et *al.* 1993), alternatively that adult fish migrate to deeper, warmer water in the autumn (Hilldén 1984). Most of the catch we observed through winter was of juveniles (75 %), winter catches of I+ fish were significantly lower compared to summer (Table 2, $p_F < 0.003$). We *may* therefore assume that at least some older wrasses disappear or migrate from shallow water during the cold season, while torpid O-group fish remain behind.

Much of the variation in catch rates (up to 41 %) was for both age groups explained by temperature (Table 2) Salinity levels affected only age 0 corkwing ($p_F < 0.01$) All were more associated with rocky and weedy habitats over non-sheltered and sparsely vegetated mudflats (Figure 3). Rock cook however seemed to be more frequently caught over mudflats than the other species; this species is often associated with eelgrass (*Zostera*) growing on this habitat. Corkwing was the only species with a strong association with the algal belt, as indicated through its significant dependence on macrophyte cover (Table 2. $p_F < 0.01$). Males of this species *are* known to use algae to construct nests in which the females lay their eggs The other species appeared more Influenced by the degree of substratum rockiness The main factors governing wrasse distribution thus *seem* to be water temperature and the presence of shelter in the form of rocky outcrops or macrophytes

The wrasses showed a great deal of distribution overlap, both in time and space. We speculate that the high level of spatial coexistence among wrasses exists because interspecific competition or resource partitioning does not occur at the habitat level, but rather at the niche or trophic level, which at least in aquatic environments is more important (Ross 1986). Wrasses are opportunistic generalists in their food choice, and have a high feeding niche width, but possess small differences in e.g. jaw morphology, enabling them to specialise if there is a shortage of preferred food items In spite of this, occurrence of rock cook is often reduced when the other two species are present in large numbers (Hilldén 1984). Presumably it loses out in competition for space with the other more permanently territorial species, especially during the reproductive season Lastly, the spatial scale at which preferences can be measured may be finer than the range we used. Perhaps the species show *more* distinctive patterns of resource use at the microhabitat level?

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BACKGROUND

Generalised linear models (GLMs; see McCullagh & Nelder 1989) form a modern, flexible and unified approach to statistical modelling. GLMs are of particular value to the analysis of data from ecological surveys, because they allow for deviation from the assumption of normality in the models. Thus one may for instance fit models with Poisson or negative binomial (negbin) error terms and logarithmic link functions. The negbin distribution in particular is frequently applied in ecology, and often gives a good approximation to typically skewed catch data (high proportion of zero catch values, low means). Many of today's statistical computer packages (e.g. S-Plus) have inbuilt options for GLMs.

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MATERIALS & METHODS

Wrasse catch data were for the present study obtained from the Masfjord "cod enhancement" sampling project (1985-92; details in Smedstad *et al.* 1994). For a part of this project a 4 by 40 m beach seine was used, with which monthly samples (July 1986 through August 1990, $n = 174$) were collected to depths of 5-10 m on ten sampling sites in Masfjord and parts of adjacent Fensfjord (Fig. 1).

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From transect diving (scuba) on each sampling site the following habitat characteristics were recorded: angle of the substratum, substratum type (soft bottom, rubble, or broken or smooth rock), degree of algal (macrophyte) cover, and degree of exposure to waves. Three to four ordinal levels were used to describe each variable (e.g. [1] absent, [2] patchy, [3] medium, [4] abundant). Temperature (°C) and salinity (S) were measured as part of the sampling procedure. Based on habitat characteristics, each site could be classified as either steep, weedy "rocky shore" habitat or shallow, sparsely vegetated "mudflat" habitat. Measured variables were fitted as factors to generalised linear ANOVA or regression models with negbin error terms, using the forward selection technique.

RESULTS & DISCUSSION

All three species were abundantly present on the sampling locations, with goldsinny numerically dominant (55% of total catch, Table 1). Up to 84 % of all sampled individuals were 0-group < 5 cm, larger (1+) fish often being more mobile and able to escape the advancing seine netting. The catch-frequency distributions of juveniles and adults alike were highly aggregated - especially for the school forming rock cook -, indicated by low values of the negbin shape or dispersion parameter *k*. Although negbin goodness-of-fit to the catch data could not in all cases be assessed (Table 1), low mean catch rates, high variance-to-mean ratios (2-12), and *k*s much less than one (0.05-0.22) suggest a good negbin approximation to the observed catch-frequency distributions.

Abundance was highly dependent on season and water temperature, all species being most active and available to capture May through August (Fig. 2). Studies have shown that wrasses assume a state of inactivity or torpor at low (< 5°C) winter temperatures (Sayer et al. 1993), alternatively that adult fish migrate to deeper, warmer water in the autumn (Hildén 1984). Most of the catch we observed through winter was of juveniles (75 %); winter catches of 1+ fish were significantly lower compared to summer ($p_r < 0.003$). We may therefore assume that at least some older wrasses disappear or migrate from shallow water during the cold season, while torpid 0-group fish remain behind.

Much of the variation in catch rates (up to 40 %) was for both age groups explained by temperature (Table 2). Salinity levels appeared to be of less significance. Goldsinny were common on both habitat types, whereas the other two species were closer associated with rocky and weedy habitats than with non-sheltered and sparsely vegetated mudflat habitats (Fig. 3). Adult rock cook were slightly more often caught over mudflats containing eelgrass (*Zostera*), in the vicinity of which it has often been reported observed (Wheeler 1969). Corkwing was the only species with a strong association with the algal belt, as indicated through its significant dependence on macrophyte cover (Table 2). Males of this species are known to use algae to construct nests in which the females lay their eggs (Hildén 1984). Macrophytes are more dominant towards the outer fjord area, perhaps also explaining the increase in abundance of corkwing here (Fig. 3). The other species appeared more influenced by the degree of substratum rockiness. The main factors governing wrasse distribution thus seem to be water temperature and the presence of shelter in the form of rocky outcrops or macrophytes.

The wrasses showed a great deal of distribution overlap, both in time and space. We speculate that the high level of spatial coexistence among wrasses exists because interspecific competition or resource partitioning does not occur at the habitat level, but rather at the niche or trophic level, which at least in aquatic environments is more important (Ross 1986). Wrasses are opportunistic generalists in their food choice, and have a high feeding niche width, but possess small differences in e.g. jaw morphology, enabling them to specialise if there is a shortage of preferred food items. In spite of this, occurrence of rock cook is often reduced when the other two species are present in large numbers (Hildén 1984). Presumably it loses out in competition for space with the other more permanently territorial species, especially during the reproductive season. Lastly, the spatial scale at which preferences can be measured may be finer than the range we used. Perhaps the species show more distinctive patterns of resource use at the microhabitat level?

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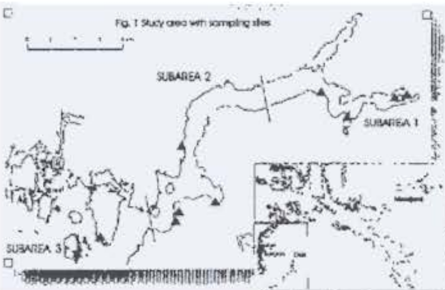
Fig. 1 Study area with sampling sites

Fig. 2 Temporal variation in wrasse catch rates in relation to temperature and salinity

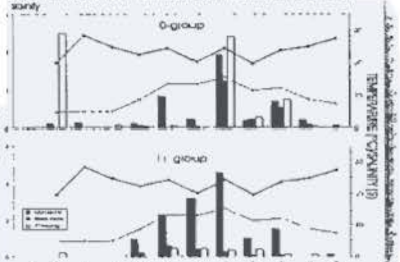

Fig. 3 Spatial effects on wrasse catch rates. Arrows denote estimates significantly different (↑ or ↓) relative to 1st level (closed)

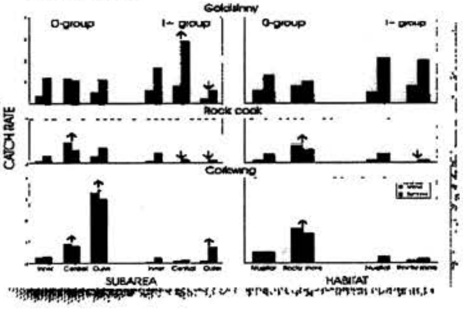

Table 1 Fit of the negative binomial to the observed catch distributions. k is the negbin dispersion parameter and G the goodness-of-fit statistic.

Species	Total	Mean	Variance	k	G	df	P(G)
0-group							
Goldsinny	254	0.86	6.178	0.22	3.84	1	0.049
Rock cook	256	0.50	5.292	0.05	1.78	0	na
Corkwing	437	0.97	11.810	0.08	1.61	0	na
1+ group							
Goldsinny	298	1.54	12.100	0.18	4.57	1	0.032
Rock cook	85	0.18	0.471	0.09	1.80	0	na
Corkwing	34	0.20	0.401	0.15	0.74	0	na

Table 2 GLMs of the effects of environmental and habitat variables on wrasse catch rates. r² is the amount of deviance explained

	0-group				1+-group			
Species	Model term	Estimate	Standard error	r²	Model term	Estimate	Standard error	r²
Goldsinny	Intercept	[illegible]	[illegible]	[illegible]	Intercept	[illegible]	[illegible]	[illegible]
	Temperature	0.36	0.044		Temperature	0.84	0.380	
					Salinity	-0.09	0.035	
	Rubble bottom	0.58	0.216		Rubble bottom	1.024	0.221	
	Broken rock	0.68	0.183		Broken rock	0.709	0.184	
Rock cook	Intercept	-14.06	4.757	0.38	Intercept	-4.48	1.586	0.39
	Temperature	0.48	0.060		Temperature	0.40	0.059	
	Salinity	0.10	0.047		Mudflat	-1.33	0.336	
	Rubble bottom	1.26	0.309		Rubble bottom	0.93	0.306	
	Broken rock	0.96	0.241		Broken rock	0.92	0.245	
Corkwing	Intercept	-0.22	1.119	0.29	Intercept	12.42	1.375	0.41
	Temperature	0.31	0.060		Temperature	0.39	0.064	
	Cover	1.83	0.338		Cover	0.82	0.286	
	Rubble bottom	0.80	0.254		Rubble bottom	1.27	0.295	
					Broken rock	0.50	0.222	