The first use of Fulton's K for assessing and comparing the conditions of intertidal fish populations

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Complete List of Authors:	Barrett, Chris; Cefas, Applied Fisheries Science & Technology Johnson, Magnus; University of Hull, CEMS Hull, Sue; University of Hull, CEMS
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The first use of Fulton's K for assessing and comparing the conditions of intertidal fish populations

Barrett, C.J[a]., Johnson, M.L[b]., Hull, S.L[b].

[a]Cefas, Pakefield Road, Lowestoft, Suffolk, U.K., NR33 0HT.

[b]CEMS, University of Hull, Filey Road, Scarborough, U.K., YO11 3AZ

Abstract

Fulton's K condition factor was applied, for the first time, to intertidal specimens of the shanny (*Lipophrys pholis*) and long-spined scorpion fish (*Taurulus bubalis*) from two English rocky shore, and two Welsh rocky shore sites, during summer 2010 and winter 2011. As both species contribute to the diet of commercial species such as cod (*Gadus morhua*) and endangered species such as the sea otter (*Enhydra lutris*), their condition may affect that of said predators. Fulton's K found that intertidal Welsh fish maintained a 'good' condition between seasons, while the intertidal English fish were in a poorer condition during winter. While condition also changed between sites of each coast, further studies are needed into their morphologies, the environmental parameters, prey availability and abundance, and sex and maturities.

'Problem'

Research has never before looked at the condition of intertidal fish species, although such analysis may aid in a better understanding of their ecology, ecosystem's health, and ecosystem's productivity. Condition is related to reproductive success (Morgan, 2004), whereby poor condition can result in lower fecundity and skipped spawning and therefore, 'good' fish condition may be indicative of optimal morphological adaptation in response to environmental conditions, predator avoidance and prey capture. Poor conditions may indicate anthropogenic or natural disturbance (Horn *et al.,* 1999) and may also affect ecosystem productivity. For example, in the North Sea (ICES area IVb) the shanny/common blenny (*Lipophrys pholis*) have been shown (Pinnegar & Platts, 2011) to contribute to the diet of cod (*Gadus morhua*), and in the Barents Sea (I) and Greenland Sea (IIb), the long-spined scorpion fish (*Taurulus bubalis*) have been found to contribute to the diets of haddock (*Melanogrammus aeglefinus*) and *G. morhua*, respectively (Pinnegar & Platts, 2011). The consumption of poor-conditioned specimens of such intertidal fish may result in poorer condition of commercial fish, or may force a shift in their diet to combat such a result, although the extent of the aftermath of such a scenario is not definitive.

The aim of this research is to determine whether Fulton's K condition factor could be used to assess differences in the condition of intertidal fish species of the U.K., between populations. Other determinants of assessing condition were considered, such as the Relative Condition Factor (LeCren, 1951) and Relative Weight (Wege & Anderson, 1978), but dismissed. The former requires the use of a 'predicted, length-specific mean weight' (Blackwell *et al.,* 2000) per population, and a difference in this value would create difficulties when comparing between populations. The latter requires defining a 'standard weight' by taking the average weight from a high number of fish from different populations. As this, similar to the other formulas, is usually applied to commercial fish, where huge (>28,000 in the case of Morgan (2004), for example) abundances can be caught and analysed with ease, determining what is a ‘high’ number of intertidal fishes is debatable and so for caution, the Relative Weight formula was not applied.

‘Study Area’

Filey Brigg (North Yorkshire; Fig. 1) protrudes east–west from the north end of Filey Bay. It is approximately 1.5 km long, with a southern side (54^{o}13’00”N 00^{o}15’58”W) sheltered from northerly and westerly prevailing winds, and a northern side (54^{o}13’01”N 00^{o}16’17”W) exposed to the prevailing north-easterly winds.

Thornwick Bay (Fig. 1), also located in Yorkshire at 54^{o}07’53”N 00^{o}06’51”W, features regionally rare intertidal and subtidal chalk reefs, sea caves and sea-cliff vegetation (Solandt and Lightfoot, 2010). It is ~0.25 km shore length, and surrounded by chalk cliffs. A freshwater stream runs onto the Bay from the south cliffs, which may influence local community structure in the immediate vicinity.

The rocky shore at Penrhos (Anglesey; Fig. 1) is located at 53^{o}18’13”N 04^{o}36’45”W. The shore is 0.9 km long, with the busy ferry port of Holyhead 0.4–1.3 km to the northwest. The shore is only exposed to the north, because it is protected by the mainland of Anglesey to the east and south, and by Holyhead and the 2.4km-long breakwater to the west and northwest, respectively.

Anglesey’s rocky shore of Rhosneigr (Fig. 1) is 0.38 km long, situated at 53^{o}13’06”N 04^{o}30’36”W, and exposed to the west and the south, with limited shelter from the Abberfraw headland to the south, but sheltered by sand-dunes on the landward side.

'Methods'

The methodology is that of Barrett *et al.,* (2013); specimen collection from all sites took place over a week of spring tides in August 2010 (summer) and January 2011 (winter) and fish were collected from small pools with the use of hand-nets (Gibson, 1999), and from larger pools using home-made fish traps (Gibson, 1999). For minimal distress (Griffiths, 2000), captured fish were anaesthetised in a solution of clove oil in seawater (Horn *et al.,* 1999). Once all obvious activity ceased, the fish were placed in sample containers with a solution of 4% formalin in seawater (Tucker and Chester, 1984) and taken to the laboratory.

Specimens were left for 3 days in 4% formalin and then transferred to 70% ethanol for another few days. Once the fixing process was complete, specimens were dried between paper towels to remove excess ethanol, dissected and the entire digestive tract removed. Then, the two more abundant specimen species (*L.pholis* and *T.bubalis*) were weighed (g) on an electronic balance, to two decimal places, and their Total Lengths (TL) were recorded (mm) using callipers.

A limitation of using Fulton's condition factor is that, as different species have different body shapes, the value ranges of *K* will be different (Blackwell *et al.,* 2000), thereby making comparisons between different species inaccurate. Therefore, the two species were tested separately. For each species, condition of specimens between seasons and sites were tested using the non-parametric, Mann-Whitney U test, as data was not normal and columns were of unequal lengths (Dytham, 2011), using Minitab 14 software. This was done to test whether between shores and seasons of a coast, the conditions of a given fish species did not significantly differ.

Table 1 displays the numbers of specimens used for condition analyses. It should also be noted that *T. bubalis* were not present at Rhosneigr and Penrhos during the winter months, and so seasonal comparisons at these sites could not be made for this species. The metric formula of Fulton's condition factor (*K*) was adapted to:

$$K = (W/L^3) \times 10^5$$

Where *K* = the condition factor, W = gutted weight (g), L = Total length (mm) and 10^5 = scaling constant. The use of such scaling constants were used by previous authors (e.g. Blackwell *et al.*, 2000; Fernandez-Jover *et al.*, 2007), and allows whole values of *K* to be compared rather than having values <1, especially in the case of the small weights and sizes of many intertidal fish, such as those sampled in the current research. Length (total) was cubed, based on the assumption that as a fish grows, it does so in three dimensions: in its length, depth and breadth.

'Results'

L. pholis were in a significantly higher condition in summer (median = 10, range = 52-543) than winter (median = 9.7, range = 48-80) in Filey (Mann Whitney U-test, W = 2206.5, df = 50 ,29, P <0.05) and the same pattern was shown at Thornwick Bay (summer median = 11, range = 61-845; winter, median = 9.6, range = 56-85): Mann Whitney U-test, W = 2132, df = 50 & 23, P = <0.001).

T. bubalis were also in significantly better condition during summer at Thornwick Bay (summer median = 17, range = 100-178; winter, median = 15, range = 80-138): (Mann Whitney U-test, W = 618, df = 23 & 20, P<0.05), but no significant difference was found at Filey between seasons.

On the west coast, *T. bubalis* were in significantly better condition at Rhosneigr, during the summer (median = 21, range = 15-429) than Penrhos, during the summer (median = 14, range = 85-143), (Mann Whitney U-test, W = 252, df = 15&10, P<0.05). In comparison, this condition of *L. pholis,* and *T. bubalis,* did not differ significantly between summer and winter at either of the two shores. Conditions of all remaining shores and seasons between the two fishes, proved non-significant.

'Discussion'

The research has identified Fulton's K as a suitable condition factor for assessing and comparing the condition of intertidal fish species, and this study could act as a baseline for prospective studies on the same fish species.

The study suggests that as *L. pholis* did not differ in condition between seasons around the Anglesey coast, it could be assumed that the Welsh population is maintaining a phenotype which is allowing better ecological success than the English population, as their condition is not hindered during the adverse winter season. When the larger specimens of intertidal fish migrate offshore, either to forage or conforming to the 'Pool Load Capability' hypothesis of Monteiro *et al.,* 2005, from a commercial fisher's perspective, this may be of ecological importance. If the findings of Pinnegar and Platts (2011) are also true of Welsh, Irish Sea, commercial fish species, and the intertidal fish species contribute highly to their diet, the commercial species may be in a 'good' condition as a result, and would therefore fetch a greater market value.

It should also be considered that the 'good' condition of Anglesey intertidal fish may be indicative of greater prey availability and more optimal environmental conditions. This is further implied by both species never being in the better condition during the winter season; only ever the same condition, or poorer.

To identify the potential cause(s) for the conditions determined by the current study, and to explain why English fish did not maintain as good a condition as the Welsh fish, future research would ideally need to incorporate fish morphologies (Webster *et al.,* 2011); environmental parameters (Wilson (1990 & 2011); prey availability and abundance (Armstrong & McGehee, 1980); and sex and maturities (Lloret *et al.,* 2002).

Summary

As contributors to the diet of commercial fish species such as cod (*Gadus morhua*) and as important prey items of the sea otter (*Enhydra lutris*), the current study could be used to help predict populations of said predators. Where intertidal fish condition is seen to be ‘poor,’ it may be predicted that predator condition/health (with particular regard to *E. lutris,* which consumes *T. bubalis* in large quantities) may deteriorate and may cause a trade-off between conserving energy and foraging less (thus reducing energy gains) and increasing foraging time to consume more of the low-conditioned intertidal fish and spending more energy in the process. The study could be combined with the conceptual model of fish coexistence by Barrett *et al.,* (2014), to help managers establish and maintain a diverse and healthy population of intertidal fishes.

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FIGURE 1 Legend

Figure 1: The location and proximity of the sites sampled along the Yorkshire coast and around the Anglesey coast (Barrett et al., 2013).

161x62mm (96 x 96 DPI)

Table 1: Numbers of specimens used for condition analysis

Shore/Season	*Lipophrys pholis*	*Taurulus bubalis*
Filey summer	50	28
Filey winter	29	7
Thornwick Bay summer	49	23
Thornwick Bay winter	23	20
Rhosneigr summer	32	15
Rhosneigr winter	6	0
Penrhos summer	11	10
Penrhos winter	3	0