Fleeting Images dynamics of North Sea ray populations

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Chapter 4
Sensitive skates or resilient rays?
Spatial and temporal shifts in ray species composition in the central and north-western North Sea between 1930 and the present day

Historic and current survey data are compared to describe the changes occurring in abundance, species richness and length-frequency of the ray community in the central and north-western North Sea between the periods 1929-1956 and 1981-1995. Survey data show that some species are no longer caught in the area, such as the common skate (*Raja batis*), some have decreased in abundance such as the thornback ray (*R. clavata*), whilst others such as the starry ray (*R. radiata*) have increased. The length-frequency relationship of all species is currently truncated at 70-79 cm, whilst individuals of up to and above 100 cm used to be common. Life-history characteristics show that the sensitivity of rays and skates to enhanced mortality is species specific. The sequence of the five most common species from most to least sensitive is: common skate > thornback ray > spotted ray (*R. montagui*) > cuckoo ray (*R. naevus*) > starry ray. This is also the order of commercial importance. The observed changes are discussed in relation to fishing.

Introduction

Rays are cartilaginous benthic fish, occupying the same spatial niche as teleost flatfish. The species have traditionally been landed for consumption (Holden, 1973; 1974a). Although they are mainly caught as bycatch, there is still a limited long-line fishery for skates off the British coast and in the past directed fisheries occurred off the European continental coast (Walker, 1996). All of the North Sea ray species have a commercial value, except for the starry ray (*Raja radiata*), which is landed incidentally in the Danish industrial fisheries. Commercial landings data on rays and skates have been collected by ICES since 1903. Landings started declining in the North Sea in the early 1920's and again in the mid-1950's, following a period of recovery during the second World War, but have remained stable during the past 15-20 years (Figure 1).

Recent trawl survey data show that the ray species in the North Sea have quite discrete distributions (Figure 2). The starry ray is abundant offshore in the central North Sea, whereas the cuckoo ray (*R. naevus*) occurs mainly in northern British coastal waters. Thornback rays (*R. clavata*) are found primarily in the coastal waters around the Thames estuary and spotted rays (*R. montagui*) off the east coast of Britain and around the Wash. The common skate (*R. batis*) is currently caught only off Shetland. However, in the past the distribution of
thornback rays and common skates was considered to be extensive throughout the central/southern and central/northern North Sea, respectively (Walker, 1996). Two other species, the shagreen ray (*R. fullonica*) and the blonde ray (*R. brachyura*) are occasionally caught in small numbers in the North Sea.

![Figure 1. Landings of rays and skates from the North Sea. Data from ICES statistics.](image)

The skate and ray species in the North Sea show a wide range in their age and length at maturity (Holden, 1973; 1974a; 1975; Vinther, 1989) and it is to be expected that each species will be affected differently by fishing. Although only the largest individuals are landed, most length and age classes are caught in trawls due to their large size at hatching (9-24 cm) and their morphology (large 'wings' and the presence of sturdy spines). Since only mature individuals can contribute to the next generation, survival during the juvenile period is a key factor. Therefore, it is to be expected that those species with the lowest length and/or age at maturity

![Figure 2. Distribution of four ray species.](image)
have the highest chance of survival at increasing levels of exploitation. The limited evidence available suggests that in the past few decades the common skate has retreated to the very northern North Sea, the thornback ray is no longer caught in the south-eastern bight and the starry ray has replaced other species in the central North Sea (Rijnsdorp et al., 1996; Walker & Heessen, 1996).

Demographic analysis of populations assumes constant age-specific rates of birth and death and a stable age distribution, with the population growing exponentially at an instantaneous rate \( r \) (Caswell, 1989; Krebs, 1989; Roff, 1992; Stearns, 1992). The basic equation of demography is the Euler-Lotka equation which is used to calculate the population growth rate (Caswell, 1989; Stearns, 1992). Brander (1981) used this equation to calculate the level of mortality at which growth rate \( r \) was zero ('replacement mortality') for a number of skate and ray species, indicating the differences in species sensitivity to fishing mortality.

In this paper the changes occurring in skate and ray species composition in the central and north-western North Sea will be explained according to the species specific sensitivity to enhanced mortality as estimated using the Euler-Lotka equation. Sensitivity analyses will demonstrate the effect of changes in the input parameters (survival, fecundity and age at maturity) on the estimate of population growth rate. The relationship between life history traits and fitness will be discussed in relation to fishing exploitation.

Materials and Methods

Survey data

Changes in abundance of demersal fish species between 1906-1909 and 1990-1995 have been analysed by Rijnsdorp et al. (1996) for the south-eastern Bight of the North Sea (Roundfish Area 6). Scottish trawl survey data for the central and northern North Sea are available for the periods 1929-1956 and 1981-1995 (Greenstreet and Hall, 1996). Data for eight skate and ray species have been analysed for this paper. Abundance estimates (catch rates) for the period 1929-1956 have been increased by 1.67 to compensate for changes in survey gear between the two periods (Greenstreet & Hall, 1996).

Leslie matrix

An age-structured Leslie matrix was used to estimate the population growth rate \( r \) at a given combination of year-class survival, fecundity and age at maturity (Caswell, 1989; Roff, 1992) according to the Euler-Lotka equation as follows:

\[
x = \omega \sum_{x = \alpha} \left[ e^{-rx} \right] * l_x * m_x
\]
where $X = \text{age class}$; $\omega = \text{age at last reproduction}$; $\alpha = \text{age at first reproduction}$; $r = \text{instantaneous rate of natural increase}$; $l_X = \text{probability of surviving from birth to beginning of age class } X$; $m_X = \text{expected number of offspring for a female in age class } X$. The population growth rate can be estimated from the dominant eigenvalue of the matrix ($\lambda$) by $\lambda = e^{rT}$. The values for fecundity, age and length at maturity and growth, used as input for the life table to estimate $r$ were taken from published data for ray and skate species in the North Sea (Holden, 1972; 1975; Holden et al., 1971; Du Buit, 1976a; 1976b; Stehmann & Bürkel, 1984; Chapter 6). See Table 1. These values were used to calculate the value of $Z$ for which $r = 0$ (replacement mortality).

The sensitivity of the estimate of population growth to changes in input parameters was estimated using an elasticity analysis (Caswell, 1989). Elasticity ($e_{ij}$) of a matrix element ($a_{ij}$) in row $i$ and column $j$ measures the proportional change in eigenvalue ($\lambda$) caused by a proportional change in mortality or fecundity. This was calculated as follows (Caswell, 1989):

$$e_{ij} = \frac{\delta \ln \lambda}{\delta \ln a_{ij}}$$

Relative changes in population growth rate brought about by a change in age at maturity were calculated by subtracting the value of $r$ at different ages from that at the estimated age at maturity.

Table 1. Reproductive parameters for females (F) of eight Raja species. Data on Leo from Wheeler (1978) and Stehmann and Bürkel (1984); data on R. batis from Du Buit (1976a); R. brachyura, R. clavata, R. montagui from Holden (1972; 1975) and Holden et al. (1971); R. naevus from Du Buit (1976a; 1976b); and R. radiata from Walker & Witte (in preparation). * = Wheeler (1969; 1978); ** = estimated as 70% of $L_{oo}$.

<table>
<thead>
<tr>
<th>Species</th>
<th>$L_{oo}$ (cm)</th>
<th>Length at maturity</th>
<th>Age at maturity</th>
<th>Fecundity (eggs/yr)</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. batis</td>
<td>237</td>
<td>180*</td>
<td>11</td>
<td>40</td>
<td>Celtic Sea</td>
</tr>
<tr>
<td>R. brachyura</td>
<td>113</td>
<td>92**</td>
<td></td>
<td>40-90</td>
<td>British west coast</td>
</tr>
<tr>
<td>R. clavata</td>
<td>85</td>
<td>72</td>
<td>10</td>
<td>60-140</td>
<td>Atlantic</td>
</tr>
<tr>
<td>R. fullonica</td>
<td>115</td>
<td>85**</td>
<td></td>
<td></td>
<td>Northern North Sea</td>
</tr>
<tr>
<td>R. montagui</td>
<td>75</td>
<td>58</td>
<td>8</td>
<td>25-60</td>
<td>Bristol Channel/west coast</td>
</tr>
<tr>
<td>R. naevus</td>
<td>70</td>
<td>59</td>
<td>8</td>
<td>90</td>
<td>Celtic Sea</td>
</tr>
<tr>
<td>R. oxyrinchus</td>
<td>156</td>
<td>120*</td>
<td></td>
<td></td>
<td>Northern North Sea</td>
</tr>
<tr>
<td>R. radiata</td>
<td>60</td>
<td>40</td>
<td>5</td>
<td>41</td>
<td>Central North Sea</td>
</tr>
</tbody>
</table>

Estimates of the current mortality on rays have been made by a length-converted catch curve (Hilborn & Walters, 1992), using length-frequency data from the North Sea as shown in Figure 2. Lengths were grouped in 1-cm or 5-cm
classes and the relative age corresponding to the midpoint of the class was estimated as \(-\ln(1-L/L_\infty)\); this was plotted against \(\ln\) abundance in each length class and the descending slope is \(1-(Z/K)\), whereby \(Z\) can be estimated. The current growth parameters \((L_\infty\) and \(K\)) were from unpublished data (Chapter 6). This estimate represents the exploited part of the population. Although all size classes, even egg capsules, are caught in fishing gear, mortality of the early life stages (eggs and \(0^+\) and \(1^+\) individuals) is expected to be higher than that of the later stages, due to a higher predation risk. Mortality due to predation of egg capsules of *R. radiata* in the North Sea has been estimated to be about 0.12 (Cox *et al.*, in press). This value is added to the above estimates for the transitions from egg to \(0^+\) and \(0^+\) to \(1^+\).

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**Figure 3.** Areas sampled in the North Sea during the Scottish survey programme (1929-1956 and 1981-1995) and the Southern Bight (Roundfish Area 6), sampled in 1906-1909 and 1990-1995.

**Results**

**Survey data**

The areas for which data were available are shown in Figure 3. Annual catch rates of six species taken in the Scottish surveys are shown in Figure 4. This shows that *Raja batis* was caught regularly during the first period, but disappeared from the area between 1956 and 1981. The spotted ray, *R. montagui*, entered the northeastern North Sea survey data in 1991 for the first time. The starry and cuckoo
rays were caught throughout the two periods, but the thornback ray became less abundant between 1981-1995 than it had been between 1929 and 1956. In Figures 5 and 6 the catches of all skates and rays in each of the four areas are shown separately for the periods 1929-1956 and 1981-1995. The overall abundance has increased in the two offshore areas (NW Central and Central) and decreased in the northern (East Shetland) area (Figure 5). There has been a marked change in the species composition in all areas (Figure 6). In the more northern and coastal areas, the common skate, the thornback ray and the cuckoo ray were also quite abundant in 1929-1956. However, by 1981-1995 the common skate and the thornback ray were no longer caught and the starry ray predominated in these areas.

Table 2. Standardised mean catch rate (numbers per hour fishing) for four Raja species in the Southern Bight (Roundfish Area 6). OT20 and OT90 = 20 and 86 foot otter trawl, respectively; BT13 and BT8 = 13 and 8 m beam trawl, respectively; GOV = 'grande ouverture verticale'. + = < 0.05; NR = not recorded (Rijnsdorp et al., 1996).

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>OT20</td>
<td>OT90</td>
<td>BT13</td>
<td>GOV</td>
<td>BT8</td>
</tr>
<tr>
<td>R. batis</td>
<td>0</td>
<td>+</td>
<td>0.1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R. clavata</td>
<td>2.8</td>
<td>0.5</td>
<td>0.2</td>
<td>+</td>
<td>0.1</td>
</tr>
<tr>
<td>R. montagui</td>
<td>0</td>
<td>NR</td>
<td>NR</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>R. radiata</td>
<td>0</td>
<td>0.2</td>
<td>+</td>
<td>+</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Data for the Southern Bight are given in Table 2 (Rijnsdorp et al., 1996). Although the estimate of abundance is dependent on the gear used, it is apparent that the thornback ray has decreased in numbers, whilst the common skate is no longer caught in the area. Changes in the length-frequency composition of the catches of the starry ray and all other species of skates and rays from the entire area are shown in Figure 7 for the two periods studied. The length-frequency of the starry ray was unchanged, but for the other species the largest size classes caught in the earlier period were no longer caught in the 1990's.

Table 3. Estimates of replacement mortality (Z, y^{-1}) for five Raja species. Data from Leslie matrix assuming a rate of increase of the population r = 0.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Replacement mortality (r=0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. batis</td>
<td>common skate</td>
<td>0.38</td>
</tr>
<tr>
<td>R. clavata</td>
<td>thornback ray</td>
<td>0.52</td>
</tr>
<tr>
<td>R. montagui</td>
<td>spotted ray</td>
<td>0.54</td>
</tr>
<tr>
<td>R. naevus</td>
<td>cuckoo ray</td>
<td>0.58</td>
</tr>
<tr>
<td>R. radiata</td>
<td>starry ray</td>
<td>0.73</td>
</tr>
</tbody>
</table>
Leslie matrix & mortality

Estimates of replacement mortality ($Z$, $y^{-1}$) based on a rate of increase of the population $r = 0$ are shown for five species in Table 3. The rank order is similar to that shown by Brander (1981), but the absolute values are different due to different input parameters. No estimate was made for the shagreen ray ($Raja pullonica$) due to lack of data. The level of total mortality which a species could withstand before $r$ drops below 0 had the following rank order:

$$R. batis < R. clavata < R. montagui < R. naevus < R. radiata$$

An increase in total mortality will lead to a decline in species abundance in the reverse order. The effect of a change in survival on population growth rate is greatest before maturity is reached (Figure 8). Changes in fecundity are only effective after maturity and have a relatively small ($R. batis$, $R. clavata$) or similar ($R. radiata$, $R. naevus$) effect on population growth rate as compared to survival. A decrease in age at maturity leads to an increase in population growth rate, if the other parameters remain the same (Figure 9).

Length-frequency distribution and length-converted catch curves for starry and thornback rays are shown in Figure 10. Estimates of total instantaneous mortality on starry and thornback rays in the North Sea, based on these catch curves, are shown in Table 4, together with the estimates of rate of population increase or decrease. Estimates for cuckoo and spotted rays were not used, because $P$ values were larger than 0.05. Using the estimates as an approximation for mortality in open sea (starry) and coastal waters (thornback), which is justified by looking at the species distribution (Figure 2), gives a range of values for the rate of population growth for five species, shown in Figure 11. For the purposes of this figure starry ray and common skate were classified as open water species ($Z = 0.70$) and cuckoo, thornback and spotted rays were classified as coastal species ($Z = 0.59$).

Table 4. Total mortality ($Z$) estimated from catch curves, with corresponding rate of increase or decrease of the population. $n =$ number of age classes. Growth parameters $L_\infty$ and $K$ from Chapter 6.

<table>
<thead>
<tr>
<th>Species</th>
<th>$L_\infty$ (cm)</th>
<th>$K$</th>
<th>Mortality</th>
<th>$n$</th>
<th>$r^2$</th>
<th>$P$</th>
<th>Rate of population change</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R. clavata$</td>
<td>109</td>
<td>0.155</td>
<td>0.588</td>
<td>12</td>
<td>0.98</td>
<td>&lt; 0.001</td>
<td>-0.073</td>
</tr>
<tr>
<td>thornback ray</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R. radiata$</td>
<td>68.7</td>
<td>0.125</td>
<td>0.700</td>
<td>17</td>
<td>0.97</td>
<td>&lt; 0.001</td>
<td>0.035</td>
</tr>
<tr>
<td>starry ray</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Figure 4. Average catch/hour for six Raja species during the entire survey period in the four areas shown in Figure 3.

Figure 5. Average catch/hour of all rays in each of the areas shown in Figure 3.
Sensitive skates or resilient rays?

Figure 6. Abundance (average catch/hour). Starry = *R. radiata*; cuckoo = *R. naevus*; thornback = *R. clavata*; skate = *R. batis*; shagreen = *R. fullonica*; sandy = *Raja circularis*; blonde = *R. brachyura*; spotted = *R. montagui*. 
Figure 7. Proportional length-frequency relationship for all four areas studied. Catches of other species represent *R. batis*, *R. brachyura*, *R. clavata*, *R. fullonica*, *R. naevus* and *R. montagui*.

**Discussion**

**Species composition and exploitation**

The role played by fisheries in bringing about the observed changes in the abundance and distribution of skates and rays in the North Sea is difficult to assess without direct observations. The available evidence seems to indicate that the skate species composition has changed in a way that could be predicted by an increase in total mortality. The observed changes in species composition show a shift to a situation in which the species with the lowest length and/or age at maturity, in this case the starry ray, dominates. The length-frequency patterns have changed accordingly and illustrate the paucity of individuals larger than 79 cm. This means that all the breeding females, and a large majority of the juveniles, of
**Sensitive skates or resilient rays?**

*Raja batis* and *R. fullonica* and *R. clavata* have disappeared, whilst the other species have lost only the very largest individuals, if at all.

The observed decline of the common skate (*R. batis*) probably coincides with a decrease in total stock size, even though the North Sea represents the eastern limit of the distribution of the species (Stehmann & Bürkel, 1984). In the past there were important skate fisheries in the North Sea, for example off the Scottish coast and on the Horn Reef off the Danish coast (Walker, 1996). However, in the past decades the species has changed from one which was relatively common and commercially important to being quite rare. Brander (1981) has described a similar situation in the Irish Sea.

![Proportional change in eigenvalue, λ (elasticity) caused by a proportional change in mortality or fecundity for four ray species.](image)

**Figure 8.** Proportional change in eigenvalue, λ (elasticity) caused by a proportional change in mortality or fecundity for four ray species.

Although the thornback ray is now caught very infrequently in the four areas covered by the Scottish surveys, it is still found off the Southeast coast of Britain (Walker & Heessen, 1996). Between 1979 and 1993 the range of this species decreased. Whereas formerly it was distributed over the entire south-western, central and northern North Sea it is now caught predominantly off the coast of Britain and Scotland (Walker & Heessen, 1996). The sporadic catches of this species in the areas sampled could be due to movements up and down the British coast.
The starry ray increased in abundance in the central North Sea between 1979 and 1993 (Walker & Heessen, 1996). The success of the starry ray, a Boreal species, in the central North Sea, rather than further North remains unexplained. Starry rays are known to be scavengers, (Templeman, 1982b) and might profit from high levels of discards from fishing vessels (although discards are not limited to the central North Sea). It is possible that there is less interspecific food competition due to removal of teleost flatfish. A similar situation was described on Georges Bank in the late 1980s, where the apparent replacement of flounder by rays was considered to be related to the dietary overlap between the species (Murawski and Idoine, 1992). The species concerned (R. erinacea) was comparable in its life history to the starry ray and was also discarded. Pauly (1994) has also described the dietary overlap of flatfish and rays. As far as the starry ray is concerned, there is plenty of opportunity for replenishment of the stock from the northern North Sea.

The spotted ray, a Lusitanian species not caught in the historical surveys, has been regularly captured off the Scottish coast since 1991. The distribution of the species, around Orkney and off the NE coast, suggests that it has entered the North Sea from the north. There appear to be two centres of distribution, one off the north-east coast of Scotland, and the other off the south-east coast of England (Walker & Heessen, 1996). In the latter region, high catches of juveniles were observed in the early 1990's (Walker & Heessen, 1996), following a series of warm winters in the late 1980's (Corten & van de Kamp, 1996). The spotted ray is
a southerly species and it is likely that the northerly limits of its distribution are in the North Sea and are determined by water temperature.

**Figure 10.** Length-frequency distribution and length-converted catch curves, based on catches from the entire North Sea during ICES IBTS surveys, 1992-1995.

Recent analyses of beam trawl data from the coastal waters of Britain and north-western Europe, show that the mean catch weight of rays is low in the central North Sea and English Channel, but higher in the shallow waters of the southern North Sea and highest off the south-western coast of the British Isles and in the Irish Sea (Rogers et al., 1998).

The patterns of exploitation have changed in the past decades. For example, although Scottish demersal fishing effort doubled in the areas NW central and E Shetland between 1960 and 1995, it diminished in the coastal area (Greenstreet & Hall, 1996). The common skate and thornback ray are landed if caught, but the starry ray is invariably discarded. Although the survival rate of the discards is unknown, it is thought to be quite high (ICES, 1995). The rank order of species sensitivity is the same as their commercial importance and size which means that those species which are most sensitive are also most heavily exploited. The species and size classes landed commercially will change in response to changing patterns of demand. For example, in the past ten years the cuckoo ray began to be
landed commercially in Scotland and juveniles of all species are often landed if larger fish are unavailable (Walker, personal observation).

![Graph of population change rates](image)

**Figure 11.** Rates of change of the population of five skate and ray species at current estimates of mortality as estimated from catch curve data. Starry and common skate classified as open water species ($Z = 0.70$) and cuckoo, thornback and spotted classified as coastal species ($Z = 0.59$).

The change in the distribution of fishing effort from coastal waters to open sea in the past 60 years (Greenstreet & Hall, 1996; Rijnsdorp & Millner, 1996) is important when taking fisheries effects into account. The spatial distribution of the individual species is especially significant and current mortality estimates, which are based on the exploited part of the population, are probably overestimates. For example, true survival rates would be higher if there were unfished (and unsampled) sources of rays; or nursery areas where juveniles could grow, and be exempt from the high (fisheries) mortality; or if there was immigration of individuals from less exploited areas. The idea of strongholds, or sources, within the North Sea, where mortality (or emigration) is lower than natality (or immigration) (Pulliam, 1988) is an appealing one from the point of view of replenishment of exploited stocks. The topography of the North Sea is highly heterogeneous and there are areas which are difficult to fish. Thornback rays, for example, are still found between the banks off the east coast of Britain and in deep, stony pits (i.e. Silver Pit). These and similar areas could function as sources of recruitment to the more exploited areas, but the very characteristic of a source (birth rate > death rate) makes it difficult to identify with classical methods. There is a real need to identify the spatial distribution of the different stages of the life cycle of the North Sea rays and skates and to make reliable estimates of fishing and discard mortality of all these stages in order to fully understand the impact of fisheries on these species.
Life history parameters

The use of fixed values for life-history parameters such as fecundity and length and age at maturity, which may have been estimated under different circumstances, can lead to an unreliable estimate of rate of population increase, and thus replacement mortality. Changes in abundance can lead to changes in life-history parameters. For example individual growth rate can increase at lower density, resulting in changes in length and age at maturity and fecundity, which may lead to a higher net reproductive rate (Roff, 1992; Gotelli, 1995). Thus density-dependent feedback can influence population size, as is implied by the logistic growth model (Krebs, 1989; Roff, 1992; Gotelli, 1995). Moreover, the traits measured at a particular moment are themselves the result of past selection pressures. It is also unknown how reliable the published data are for most of the skate and ray species, as many studies were limited by numbers of individuals, area or season. The sensitivity analysis illustrates how important the estimates of juvenile survival and age at maturity are to the outcome of the matrix analysis.

Changes in age and/or length at maturity and fecundity as a result of changes in growth patterns is a subject of ongoing research. Initial results indicate that thornback rays have a higher length at age now than in the past (Holden, 1972) and reach maturity sooner (Chapter 6). Any compensatory changes occurring should ultimately result in an increase in juvenile survival in order to be effective, regardless of species. However, if fishing is the major selective pressure in operation, then only those species which can exhibit a fast enough compensatory response will survive. From Figures 9 and 10, it is apparent that, in theory, a smaller compensatory change is necessary for the starry ray to be able to withstand an increase in total mortality than for the other species. If this actually occurs is unknown and without experimental evidence, it is speculative to compare these species-specific responses to fishing exploitation.

Although there have been temporal and spatial shifts in species composition, the ray and skate trophic and spatial niche remains occupied. It is likely that there have been changes in predator-prey relationships resulting from the observed changes in the size composition of the populations, i.e. the marked reduction in the number of large skates and rays in the North Sea. However a detailed analysis goes beyond the scope of this paper.

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