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Research article

Risk assessment of hull fouling as a vector for marine non-natives in Scotland

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Abstract

To determine the importance of recreational boating as a vector for distributing marine organisms, including non-native species, the extent of hull fouling species on recreational yachts in Scotland was assessed. In August 2006, up to 100 yachts in each of the ten largest marinas in Scotland were ranked using a fouling index. 23 yacht owners were asked a questionnaire to determine the importance of general characteristics of the yacht and its travel history in relation to the level of hull fouling. 59 % of the yachts surveyed were found to have macrofouling attached to their hulls, suggesting that recreational boating has a high potential for distributing marine species throughout Scotland. Increased age of the antifouling paint, as well as long stationary periods and reduced sailing activity increase the risk of macrofouling species attaching to hulls. Recreational boating must be considered as a high risk vector for non-native species in Scotland.

Key words: Hull fouling, recreational boating, distribution, marine, non-natives, Scotland

Introduction

Hull fouling is a significant vector for the introduction of non-native species (Eno et al. 1997, Cohen and Carlton 1998, Hewitt et al. 1999, Gollasch 2002). Non-native species were identified in 98 % of samples taken from commercial ship hulls in the North Sea (Gollasch 2002). Traditionally, hull fouling has been studied on commercial tankers and container ships (e.g. Godwin 2001, Gollasch 2002, Coutts and Taylor 2004). Recreational vessels were considered less likely to support extensive fouling accumulations due to a frequent cleaning regime, their relatively fast speed, and those on long voyages were unlikely to reside for long periods of time (>30 d) in any single port (Carlton and Hodder 1995). However, recreational boating can be responsible for the spread of non-native species, especially on a local scale (Johnson and Carlton 1996, Johnson et al. 2001, Bax et al. 2002). It is the local, secondary spread within a country that will ultimately determine the extent of the economic and environmental impact of a non-native species (Lodge et al. 1998). The proliferation of marinas for recreational vessels over recent decades is a worldwide phenomenon (Minchin et al. 2006) and recreational vessels have become increasingly implicated in the spread of marine non-native species (e.g. *Undaria pinnatifida* (Harvey) Suringar 1872, Hay 1990; *Mytilopsis sallei* Recluz 1849, Field 1999). Fouling species are generally small-sized sedentary, burrow-dwelling or clinging species (Galil and Zenetos 2002), larger fouling species distributed outside of their native range include the serpulid polychaete, *Ficopomatus enigmaticus* Fauvel 1923 (Zibrowius 1979) the bryozoan, *Tricellaria inopinata* d'Hondt and Occhipinti-Ambrogi 1985 (Occhipiniti-Ambrogi and d'Hondt 1994) and the non-native marine algae *Codium fragile* spp. *tomentosoides* (van Goor) Silva 1955 and *Undaria pinnatifida* (Harvey) Suringar 1872 (Bird et al. 1993; Fletcher and Farrell 1998).

There has been no systematic survey along coastal areas of individual countries in the northern hemisphere to assess the importance of recreational boating in the distribution of marine non-natives. Although, a recent study by Minchin et al. (2006) lists several cases where small craft have been recorded or implicated in the introduction of non-indigenous species in the northern hemisphere. In New Zealand, Floerl et al. (2005) used quantitative screening techniques to assess the importance of ocean-going yachts in the transport of organisms. An ordinal rank scale was found to provide reliable indications of the abundance and diversity of fouling organisms. However, classification tree models explained comparatively little of the fouling variation, whereas the age of the antifouling toxic paint on yacht hulls was considered the principal risk factor for hull fouling.

To date, four non-native species have been described from marinas in Scotland (*Caprella mutica* Schurin 1935, *Codium fragile* spp. *tomentosoides*, *Sargassum muticum* (Yendo) Fensholt 1955 and *Styela clava* Herdman 1882; Ashton et al. (2006). These species are most likely spread, and others potentially introduced on the submerged surfaces of recreational boats. The aim of this study was to use a ranking scale method and a boat-owners questionnaire based on the study by Floerl et al. (2005) to assess the importance of recreational boating as a vector for marine species in Scotland.

Methods

The ten largest marinas in Scotland were surveyed between the 21st and 24th August 2006 [see Ashton et al. (2006) for marina details]. In each marina, up to 100 yachts were ranked according to a ‘fouling index’ (Table 1). A fouling rank of 2 or greater indicates the presence of macrofouling species, whilst rank 3 relates to the presence of at least one or more taxa occurring in patches on the hull. Ranks 4 and 5 relate to differences in the percentage coverage of more than one taxa (16 - 40 % and 41 -100 %, respectively). The yacht hulls were ranked using surface observations which may not be a true indication of the extent of fouling on deeper, submerged surfaces, but was found to be a reliable indicator by Floerl et al. (2005).

Table 1. Fouling index ranks according to Floerl et al. 2005

Rank	Description
0	No visible fouling. Hull entirely clean, no biofilm on visible submerged parts of the hull.
1	Slime fouling only. Submerged hull areas partially or entirely covered in biofilm, but absence of any macrofouling.
2	Light fouling. Hull covered in biofilm and 1-2 very small patches of macrofouling (only one taxon). 1-5 % of visible submerged surfaces fouled.
3	Considerable fouling. Presence of biofilm, and macrofouling still patchy but clearly visible and comprised of either one single or several different taxa. 6-15 % of visible submerged surfaces fouled.
4	Extensive fouling. Presence of biofilm and abundant fouling assemblages consisting of more than one taxon. 16-40 % of visible submerged surfaces fouled.
5	Very heavy fouling. Diverse assemblages covering most of visible hull surfaces. 41-100 % of visible submerged surfaces fouled.

Where yacht owners were present, they were asked a series of questions relating to general information about the boat, including origin and hull material, vessel maintenance and travel history in the past 12 months. Questions were designed to detect variables which have been shown to influence hull fouling on commercial and private vessels (Coutts 1999, Floerl 2002). Twenty-three questionnaires were completed in total.

Results and Discussion

59 % of yachts surveyed had a fouling rank of 2 or greater (Figure 1); these yachts had evidence of macrofouling species. Yachts of all ranks were found in the survey (Figure 1). A further 20 % of yachts were ranks 4 or 5, indicating extensive and heavy macrofouling with multiple species. Confirmation of the reliability of the surface fouling rank as an indicator of the level of fouling on submerged yacht surfaces is still required in UK waters, although this method has proven reliable in New Zealand (Floerl et al. 2005); care must be taken to include sessile and motile species in this analysis (Gollasch 2002, Fofonoff et al. 2003). In New Zealand, only 15 % of yachts

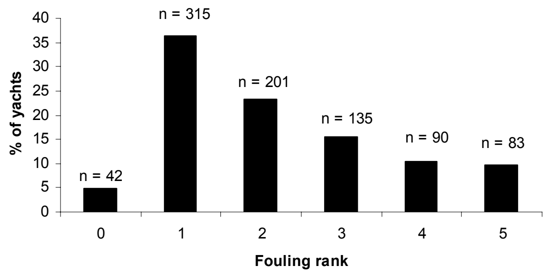

Figure 1. Distribution of fouling ranks of surveyed yachts in ten Scottish marinas (n = 866)

surveyed had fouling ranks of 2 or greater (Floerl et al. 2005); this may be due to the use of yachts from overseas in the New Zealand study compared to both international and domestic yachts surveyed in the present study. In order for international ships to arrive at New Zealand, they must cross oceanic waters where macrofouling organisms are likely to be dislodged, prevented from feeding, or are unable to survive changes in environmental conditions experienced during oceanic voyages (Pyefinch 1950, Carlton and Hodder 1995). It is also unlikely that the yachts remain in a single port for a period long enough to accumulate fouling species (Carlton and Hodder 1995).

The origin of the majority of the yachts surveyed in the present study was within the UK (Table 2). While recreational yachts may not be important for dispersing non-natives over long distances, they are more likely to result in successful introductions at a local scale. 78 % of species identified on commercial ships were considered unlikely to succeed in North Sea habitats due to the difference in climatic conditions from their native habitat (source regions experiencing a warm-temperate or tropic climate; Gollasch 2002). Recreational yachts frequently travel short distances and there is a high probability, therefore, that the source and recipient areas will be within the same climatic region, and that the fouling species will survive in the receiving habitat if similar environmental conditions exist. There is strong variation, however, in the potential of domestic craft to spread non-native species (Minchin et al. 2006). Fouling species have been shown to successfully spawn and recruit from boat hulls within marinas (Apte et al. 2000). Recreational boating may, therefore, be an important vector in the secondary spread of marine non-native species. Further investigation is required on the level of risk that this vector presents in the secondary spread of non-native species.

The age of antifouling paint was on average higher in yachts with a fouling rank of 2 or greater (Table 2). The age of the antifouling application on yacht hulls is considered the principal risk factor for hull fouling; most paints will only prevent fouling for 9-18 months (Floerl et al. 2005). There were also differences in the vessel maintenance record between yachts with and without macrofouling. In a study of commercial ships arriving at Hawaii (Godwin 2001), the most serious hull fouling vectors were vessels that were poorly maintained. The cleaning record was considered less important when explaining the variation in hull fouling of yachts in the present survey and that of Floerl et al. (2005).

Table 2. Results from questionnaire, grouped according to fouling rank (a rank of ≥2 indicates presence of macrofouling species)

Rank	<2, n = 16	≥2, n = 7
General information and vessel maintenance		
1 Origin	UK (1 from Sweden)	UK
2 Hull material	Fibreglass	Fibreglass (1 wood)
3 Age of anti-fouling paint (months)	5.42±5.31(SD)	9.14±7.84(SD)
4 Professional/ private cleaning	25% professional	43% professional
5 Manual hull cleaning?	36% yes	71% yes
6 Time since last manual clean (months)	6.48±4.29(SD)	6.43±4.27(SD)
Travel history in last 12 months		
7 Last port of call	Within Scotland	Within Scotland (1 Ireland)
8 Time in last port (months)	2.10±1.83(SD)	4.14±7.44(SD)
9 Longest period stationary (months)	1.95±1.84(SD)	3.93±3.94(SD)
10 Sailing activity (days)	52.7±66.6(SD)	23.6±16.1(SD)

Travel history varied between yachts with different fouling ranks (Table 2). Yachts which had spent a long time in their most recent port of call, a long stationary period, and engaged in less sailing activity in the last 12 months were more likely to have macrofouling species. This is not considered a surprising result as there is more opportunity for settlement and establishment of fouling species on these stationary yachts.

Non-native species have been found on yacht hulls on the west coast of Scotland (e.g. *Caprella mutica*, pers. obs.). Once introduced to a marina, there is a high probability that a species would be spread further via recreational yacht hulls; most likely to habitats of similar environmental conditions where the species can successfully establish. Both nationally and internationally, hull fouling is as yet an unmanaged vector and represents a significant risk for the introduction of non-native species (Minchin and Gollasch 2003, Hewitt et al. 2004). In New Zealand, hull cleaning guidelines have been introduced (http://www.biodiversity.govt.nz/seas/biosecurity) and developed. Australia has also implemented successful control procedures at man-made marinas and has protocols in place for the management of future non-natives (Bax et al. 2002). European coastal areas should be prepared to implement similar management procedures. Consideration of recreational boating as a vector for marine non-natives must be included in all proactive management plans for marine non-native species.

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