13 Water Sports and Water-Based Recreation

Chapter Summary
This chapter first lists some of the different water sport disciplines and then defines those on which the chapter will focus—motorboating/powerboating, canoeing, kayaking, jet skiing, rafting, rowing, sailing, surfing, water skiing, sailing, and windsurfing—distinguishing between motorised and non-motorised activities. It then examines relative and actual participation numbers. The final part of the chapter focuses on specific environmental impacts of water sports: physical impacts to aquatic vegetation, the spread of invasive species, erosion of banks and shores, water pollution and its costs. There is discussion about the impacts of water sports on wildlife as well as the chemical impacts on water sports (heavy metals, hydrocarbons). The final section considers the management of these activities and gives examples of ways in which users can be educated.

13.1 Definitions

The term water sports includes a wide range of activities both in the water and on the water surface. Chapter 14 deals with some of the underwater activities: scuba diving and snorkelling. This chapter focuses on some of the more popular water recreational activities which take place on the water surface. Table 13.1 shows a list of the potential activities, with those in bold to be considered in this chapter.

13.1.1 Non-motorised Water Sports

It is generally agreed that non-motorised watercraft have less impact on the environment than motorised craft. While non-motorised craft have little or no impact on the water over which they pass, there may be impacts on the shore or river bank as well as disturbances to fish, plants, and wildlife.

13.1.1.1 Canoeing

Canoeing is an activity which involves paddling a canoe with a single-bladed paddle (Fig. 13.1A–D). In some parts of Europe, canoeing refers to both canoeing and kayaking (see Sect. 13.1.1.2), with a canoe being called an "Open Canoe" or sometimes, "Canadian Canoe" (after its origins as an ancient mode of transportation, used by *voyageurs* to transport beaver furs across Canada). Canoeing can be combined with other activities such as canoe camping (Fig. 13.1B), or where canoeing is merely a transportation method used to accomplish other activities. Most present-day canoeing is done as or as a part of a sport or recreational activity.

A recreational form of canoeing is canoe camping, the open canoe being very suited to

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Table 13.1 List of potential water-based activities which take place on the water surface

Activity name	Description
Barefoot skiing	Water skiing without skis
Boating	The use of small boats manoeuvred without an engine (i.e. with paddles, oars, or poles)
Boat racing/ motorboating/ powerboating	Use of powerboats with engines, often used to participate in races
Bodyboarding	Similar to surfing, but the board is smaller and the person (normally) lies down on the board
Cable skiing	Similar to wakeboarding but with cables for artificial manoeuvring
Canoeing	Canadian or open canoes manoeuvred by a single blade paddle. Normally one person kneeling or two persons seated
Canoe polo	A competitive sport which normally takes place between two teams of five on a pitch which can be set up in swimming pools or any stretch of flat water
Dragon boat racing	Dragon boats are the basis of the team paddling sport of dragon boat racing, a water sport which has its roots in an ancient folk ritual of contending villagers, which has been held for over 2000 years throughout southern China. Teams of 20 paddlers race each other
Fishing	The recreation and sport of catching fish. See Chap. 15
Flyboard	A Flyboard rider stands on a board connected by a long hose to a watercraft. Water is forced under pressure to a pair of boots with jet nozzles underneath which provide thrust for the rider to fly up to 15 m (49 ft) in the air or to dive headlong through the water down to 2.5 m (8 ft). A Flyboard is a brand of hydroflighting device which supplies propulsion to drive the Flyboard into the air to perform a sport known as hydroflying
Flowrider	A water park attraction to simulate the riding of waves in the ocean. In the late 1980s, a patent was taken out for “a wave-forming generator for generating inclined surfaces on a contained body of water.” The rider surfs an artificial wave on a small surfboard
Jet skiing	Jet Ski is a proper noun and registered trademark of Kawasaki. The stand-up Kawasaki Jet Ski was the “first commercially successful” personal watercraft in America, having been released in 1972. There is normally one driver and up to two passengers
Kayaking	Kayaking is the use of a kayak for moving across water. It is distinguished from canoeing by the sitting position of the paddler and the number of blades on the paddle. A kayak is a low-to-the-water, canoe-like boat in which the paddler sits facing forward, legs in front, using a double-bladed paddle to pull front-to-back on one side and then the other in rotation[1]. Most kayaks have closed decks, although sit-on-top and inflatable kayaks are growing in popularity as well
Kiteboarding	Kiteboarding is an action sport combining aspects of wakeboarding, snowboarding, windsurfing, surfing, paragliding, skateboarding, and sailing into *one* extreme sport. A kiteboarder harnesses the power of the wind with a large controllable power kite to be propelled across the water, land, or snow. On water, a kiteboard, similar to a wakeboard or a small surfboard, with or without footstraps or bindings, is used
Kitesurfing	Kitesurfing is a style of kiteboarding specific to wave riding, which uses standard surfboards or boards shaped specifically for the purpose. On land, a mountain board or foot-steered buggy is used while skis or snowboards can be used in snow. There are different styles of kiteboarding, including freestyle, freeride, speed, course racing, wakestyle, big air, park, and surfing.[1] In 2012, the number of kitesurfers was estimated by the ISAF and IKA at 1.5 million persons worldwide
Kneeboarding	Kneeboarding is an aquatic sport where the participant is towed on a buoyant, convex, and hydrodynamically shaped board at a planing speed, most often behind a motorboat
Paddleboarding	Paddleboarding participants are propelled by a swimming motion using their arms while lying, kneeling, or standing on a paddleboard or surfboard in the ocean. A derivative of paddleboarding is stand-up paddle surfing and stand-up paddleboarding (SUP). Paddleboarding is usually performed in the open ocean, with the participant paddling and surfing unbroken swells to cross between islands or journey from one coastal area to another
Parasailing	Parasailing, also known as parascending or parakiting, is a recreational kiting activity where a person is towed behind a vehicle (usually a boat) while attached to a specially designed canopy wing that reminds one of a parachute, known as a parasail wing

(continued)

Table 13.1 (continued)

Activity name	Description
Rafting/white-water rafting	Rafting and white-water rafting are recreational outdoor activities which use an inflatable raft to navigate a river or other body of water. This is often done on white water or different degrees of rough water
Rowing	Rowing is the act of propelling a boat using the motion of oars in the water, displacing water, and propelling the boat forward. The difference between paddling and rowing is that rowing requires oars to have a mechanical connection with the boat, while paddles are handheld and have no mechanical connection
Sailing/yachting	Sailing employs the wind—acting on sails, wingsails, or kites—to propel a craft on the surface of the water (sailing ship, sailboat, windsurfer, or kitesurfer), on ice (iceboat) or on land (land yacht) over a chosen course, which is often part of a larger plan of navigation
Sit-down hydrofoiling	The sit-down hydrofoil, first developed in the late 1980s, is a variation on water skiing, a popular water sport. When towed at speed, by a powerful boat or some other device, the board of the hydrofoil "flies" above the water surface and generally avoids contact with it, so the ride is largely unaffected by the wake or chop of the water and is relatively smooth. The air board is a modified hydrofoil where the skier stands up
Skimboarding	Skimboarding (or skimming) is a boardsport in which a skimboard (much like a surfboard but smaller and without fins) is used to glide across the water's surface to meet an incoming breaking wave and ride it back to shore
Skurfing	Water skurfing is a form of water skiing that uses a surfboard or similar board instead of skis. The skurfer is towed behind a motorboat at planing speed with a tow rope similar to that of kneeboarding and wakeboarding. It shares an advantage with kneeboarding in that the motorboat does not require as much speed as it does for water skiing
Surfing	Surfing is a surface water sport in which the wave rider, referred to as a surfer, rides on the forward or deep face of a moving wave, which is usually carrying the surfer towards the shore. Waves suitable for surfing are primarily found in the ocean but can also be found in lakes or in rivers in the form of a standing wave or tidal bore
Wakeboarding	Wakeboarding is a surface water sport which involves riding a wakeboard over the surface of a body of water. The wakeboard is a small, mostly rectangular, thin board with very little displacement and shoe-like bindings mounted to it. The wakeboard is usually towed behind a motorboat, typically at speeds of 30–40 km/h (18–25 mph), depending on the board size, weight, type of tricks, and comfort
Water skiing	Water skiing (also waterskiing or water-skiing) is a surface water sport in which an individual is pulled behind a boat or a cable ski installation over a body of water, skimming the surface on two skis or one ski. The sport requires sufficient area on a smooth stretch of water, one or two skis, a tow boat with tow rope, three people (depending on state boating laws), and a personal flotation device
Windsurfing	Windsurfing is a surface water sport that combines elements of surfing and sailing. It consists of a board usually 2.5 to 3 m long, with displacements typically between 60 and 250 litres, powered by wind on a sail. The rig is connected to the board by a free-rotating universal joint and consists of a mast, boom, and sail. The sail area generally ranges from 2.5 m^2 to 12 m^2 depending on the conditions, the skill of the sailor, the type of windsurfing being undertaken, and the weight of the person windsurfing

carrying large loads (Fig. 13.1B). Other forms include a wide range of canoeing on lakes, slow-moving rivers (Fig. 13.1A), fast-moving rivers (Fig. 13.1C), and even the sea (Fig. 13.1D). Canoe sailing is another strand within the sport, as is canoe poling (Fig. 13.1E) where the canoeist stands in the canoe (slightly back from centre) and propels and steers the craft with a 12 ft. aluminium pole (Fig. 13.1E).

British Canoeing (https://www.britishcanoeing.org.uk/) is the national governing body for paddlesports in the UK. Formerly known as the British Canoe Union (founded in 1936), Canoe England, and GB Canoeing, these bodies have now come together under one unified umbrella organisation for the home nation associations in Scotland (Scottish Canoe Association), Wales (Canoe Wales), and Northern Ireland (Canoe Association Northern Ireland). British Canoeing is responsible for leading and setting the overall framework for all the national associations and includes areas such as coaching,

Fig. 13.1 (A) Tranquil open canoe journey on the River Stour, Southern England. Photo by Tim Stott. (B) Open canoe camping. The canoe is ideal for transporting heavy loads. Photo by Tim Stott. (C) The author solo paddling an open canoe on Grade II water of the River Dee, North Wales. Photo by Clive Palmer. (D) The open canoe can be rigged for sailing. Photo by Tim Stott. (E) In canoe poling the canoeist stands in the canoe (slightly back from centre) and propels and steers the craft with a 12 ft. aluminium pole. The US National Canoe Poling Championships on the Meramec River, Missouri, USA. Photo by Tim Stott

competition, and representing canoeing interests at a UK level.

13.1.1.2 Kayaking

Kayaking is the use of a kayak for moving over water. It is distinguished from canoeing by the sitting position of the paddler and the number of blades on the paddle. A kayak is a low-to-the-water, canoe-like boat in which the paddler sits facing forward, legs in front, using a double-bladed paddle to pull front-to-back on one side and then the other in rotation (Fig. 13.2A–C). Most kayaks have closed decks, although sit-on-top and inflatable kayaks (Fig. 13.2F) are growing in popularity as well.

Kayaks were created thousands of years ago by the Inuit, formerly known as Eskimos, of the northern Arctic regions. They used driftwood and sometimes the skeleton of whale, to construct the frame of the kayak, and animal skin, particularly seal skin, was used to create the body. The main purpose for creating the kayak, which literally translates to "hunter's boat" was for hunting and fishing. Modern kayaks are made from plastic, though some specialist slalom kayaks are still made from glass fibre or Kevlar.

13.1.1.3 Rafting/White-Water Rafting

Rafting and white-water rafting are recreational outdoor activities which use an inflatable raft to navigate a river or other body of water. This is often done on white water or different degrees of rough water (Fig. 13.2D, E). Dealing with risk and the need for teamwork is often a part of the experience. This activity as a leisure sport has become popular since the 1950s, evolving from individuals paddling 3.0 m (10 ft) to 4.3 m (14 ft) rafts with double-bladed paddles or oars to multi-person rafts propelled by single-bladed paddles and steered by a person at the stern or by the use of oars. Rafting on certain sections of rivers is considered an extreme sport, while other sections are not so extreme or difficult. The International Rafting Federation, often referred to as the IRF, is the worldwide body which oversees all aspects of the sport.

13.1.1.4 Rowing

Rowing is the act of propelling a boat using the motion of oars in the water, displacing water, and propelling the boat forward. The difference between paddling and rowing is that rowing requires oars to have a mechanical connection with the boat, while paddles are handheld and have no mechanical connection. In some regions, rear-facing systems are used, while in other places forward-facing systems prevail, especially in crowded areas such as in Venice, Italy, and in Asian and Indonesian rivers and harbours. In another system called sculling, a single oar extending from the stern of the boat is moved back and forth under water somewhat like a fish tail, and quite large boats can be moved.

13.1.1.5 Sailing/Yachting

Sailing employs the wind acting on sails to propel a craft on the surface of the water (sailing ship, sailboat, windsurfer, or kitesurfer), on ice (iceboat), or on land (land yacht) over a chosen course, which is often part of a larger plan of navigation. The forces transmitted via the sails are resisted by forces from the hull, keel, and rudder of a sailing craft. In the twenty-first century, most sailing represents a form of recreation or sport (Fig. 13.3A). Recreational sailing or yachting can be divided into racing (Fig. 13.3B) and cruising (Fig. 13.3C). Cruising can include extended offshore and ocean-crossing trips, coastal sailing within sight of land, and day sailing.

13.1.1.6 Windsurfing

Windsurfing is a surface water sport that combines elements of surfing and sailing. It consists of a board usually 2.5 to 3 m (7–9 ft) long, with displacements typically between 60 and 250 litres, powered by wind on a sail (Fig. 13.3D). The rig is connected to the board by a free-rotating universal joint and consists of a mast, boom, and sail. The sail area generally ranges from 2.5 to 12 m^2 depending on the conditions, the skill of the sailor, the type of windsurfing being undertaken, and the weight of the person. Windsurfing can take place on lakes, reservoirs, estuaries, and the open sea.

Fig. 13.2 (A) Recreational kayaker descends a rapid on the upper Afon Tryweryn, North Wales. Photo by Tim Stott. (B) Recreational kayaker at the same location as part (A) with the kayak almost totally under the water. A spray deck fitted over the cockpit prevents water ingress. Photo by Tim Stott. (C) A recreational white-water kayaker using a high-volume kayak to descent "big water". Photo by Tim Stott. (D) White-water rafting on the upper Afon Tryweryn, North Wales. Photo by Tim Stott. (E) White-water rafting on a wave on the Durance River, France. Note the kayakers in the foreground. Photo by Tim Stott. (F) A typical "beach" on the Durance River, France, in summer gives an impression of the popularity of the sport. Note the red inflatable kayak in the foreground. Photo by Tim Stott

Fig. 13.3 (A) Dinghy sailing in Liverpool Marina. Photo by Tim Stott. (B) Yachts racing on the Mersey Estuary near Liverpool. Photo by Tim Stott. (C) Cruising boats in Liverpool Marina. Photo by Tim Stott. (D) Windsurfing in the inland sea at Valley on Anglesey in North Wales. Photo by Tim Stott. (E) Surfing at Bundoran, Northern Ireland. Photo by Tim Stott

13.1.1.7 Surfing

Surfing is a surface water sport in which the wave rider, referred to as a surfer, rides on the forward or deep face of a moving wave, which is usually carrying the surfer towards the shore (Fig. 13.3E). Waves suitable for surfing are usually found in the ocean but can also be found on rivers as standing waves or tidal bores. However, surfers can also use artificial waves such as those from boat wakes and the waves created in artificial wave pools.

The term surfing refers to the act of riding a wave, regardless of whether the wave is ridden with a board or without a board, and regardless of the stance used. The native peoples of the Pacific, for instance, did so on their belly and knees. The modern-day definition of surfing, however, most often refers to a surfer riding a wave standing up on a surfboard; this is also referred to as stand-up surfing. Another prominent form of surfing is bodyboarding, when a surfer rides a wave on a bodyboard (which is about one third of the length of a surfboard), either lying on their belly, drop knee, or sometimes even standing up on a bodyboard.

13.1.2 Motorised Water Sports

Jet Ski is the brand name of a personal watercraft (PWC) first manufactured by Kawasaki, a Japanese company in the 1970s. The term is often used generically to refer to any type of PWC used mainly for recreation, and it is also used as a verb to describe the use of any type of PWC. A runabout style PWC typically carries up to three people seated in a configuration like a typical bicycle or motorcycle. With the introduction of the Jet Ski, in cooperation with aftermarket companies and enthusiasts, Kawasaki helped in creating the United States Jet Ski Boating Association (USJSBA). In 1982 the name was changed to the International Jet Sports Boating Association (IJSBA).

Water skiing is a surface water sport in which an individual is pulled behind a boat or a cable ski installation over a body of water, skimming the surface on two skis or one ski. The sport requires sufficient area on a smooth stretch of water, one or two skis, a tow boat with tow rope, three people (depending on state boating laws), and a personal flotation device. In addition, the skier must have adequate upper and lower body strength, muscular endurance, and good balance.

A motorboat, speedboat, or powerboat is a boat which is powered by an engine. Some motorboats have an outboard motor installed on the rear (Fig. 13.4), others are fitted with inboard engines. Motorboats vary greatly in size and configuration, from the 4 m, open centre console type to the luxury mega-yachts capable of crossing an ocean.

One thing which all these motorised watercraft have in common is a propeller which, as we shall see later, has the potential to inflict damage to aquatic ecosystems.

13.2 Participation Numbers

In the USA, during the 2016 calendar year, a total of 24,134 online interviews were carried out with a nationwide sample of individuals and households from the US Online Panel of over one million

Fig. 13.4 Small powerboat. Photo by Terry Mitchell

people operated by Synovate/IPSOS (Outdoor Foundation 2017). A total of 11,453 individual and 12,681 household surveys were completed. The total panel is maintained to be representative of the US population for people ages six and older. Over sampling of ethnic groups took place to boost response from typically under responding groups. The 2016 participation survey sample size of 24,134 completed interviews provides a high degree of statistical accuracy.

As can be seen in Table 13.2, the Outdoor Foundation (2017) survey for the USA provided data for eight water sport disciplines. The rank order in terms of the greatest number of participants in 2016 was:

- *Canoeing*—10,046,000 participants in 2016 and a −1.1% decrease over the previous three years.
- *Kayaking* (recreational)—10,017,000 participants in 2016 and a three-year increase of 14.9%.
- *Sailing*—4,095,000 participants in 2016 and a three-year increase of 4.6%.
- *Rafting*—3,428,000 participants in 2016 and a three-year decrease of −10.6%.
- *Stand-up paddling*—3,220,000 participants in 2016 and a massive three-year increase of 61.6%.
- *Kayaking* (sea/touring)—3,124,000 participants in 2016 and a three-year increase of 16.0%.
- *Surfing*—2,793,000 participants in 2016 and a three-year increase of 5.1%.
- *Kayaking* (white water)—2,552,000 participants in 2016 and a three-year increase of 18.9%.
- *Boardsailing/windsurfing*—1,737,000 participants in 2016 and a three-year increase of 31.2%.

If we total all three kayaking disciplines, there was a total of 15,693,000 participants in 2016, making it the most popular of the disciplines in the survey. Stand-up paddling showed by far the greatest three-year increase of 61.6%.

Cordell's (2012) survey showed kayaking (Table 13.3) as having 14,200,000 participants in the 2005–2009 period with a 103.8% increase between the 1999–2001 and 2005–2009 periods. Comparing that with the Outdoor Foundation's (2017) data, it appears that kayaking had continued to increase after Cordell's 2005–2009 survey. Sailing had the second greatest numbers participating within the water sports disciplines with 10,400,000 in the 2005–2009 periods with a decrease of −0.4% between 1999–2001 and the 2005–2009 survey. Rowing had the third greatest numbers participating within the water sports disciplines with 9,400,000 in the 2005–2009 periods with an increase of 8.9% between the 1999–2001 and the 2005–2009 surveys. Surfing had 2,000,000 participants in 2005–2009 (a 46.3% increase between the 1999–2001 and the 2005–2009 surveys), and windsurfing had 600,000 participants in 2005–2009 (a −10.1% decrease between the 1999–2001 and the 2005–2009 surveys).

Bowker et al. (2012) projected changes in total outdoor recreation participants between 2008 and 2060 (Table 13.4). There was an estimated 62 million participants in 2008 taking part in motorised water activities (motorboating, water skiing, PWC), and this was predicted to become 87–112 million by 2060. For non-motorised floating water activities (canoeing, kayaking, and rafting), there was an estimated 40 million participants in 2008 taking part, and this was predicted to increase to 52–65 million by 2060.

Table 13.5 shows the changes over the same period for the total number of outdoor recreation days. There was an estimated 958 million days in 2008 where people took part in motorised water activities (motorboating, water skiing, PWC) and this was predicted to become 1304–1806 million days by 2060. For non-motorised floating water activities (canoeing, kayaking, and rafting), there was an estimated 262 million days in 2008 where people took part, and this was predicted to increase to 338–422 million days by 2060 (Bowker et al. 2012).

In England, data are available from the Sport England's Active People Survey (APS). In terms of water sports, Sport England included rowing, sailing, and canoeing in this survey. Table 13.6 shows that there was an estimated 83,400 rowing participants (0.19% of the population of England)

Table 13.2 Outdoor participation by activity (ages 6+) in the USA, 2006–2016 (The Outdoor Foundation 2017, p. 8)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	3-year change (%)
Adventure racing	725	698	920	1089	1339	1065	2170	2213	2368	2864	2999	35.5
Backpacking overnight >¼ mile from vehicle/home	7076	6637	7867	7647	8349	7095	8771	9069	10,101	10,100	10,151	11.9
Bicycling (BMX)	1655	1887	1904	1811	2369	1547	2175	2168	2350	2690	3104	43.2
Bicycling (mountain/ non-paved surface)	6751	6892	7592	7142	7161	6816	7714	8542	8044	8316	8615	0.9
Bicycling (roads/ paved surface)	38,457	38,940	38,114	40,140	39,320	40,349	39,232	40,888	39,725	38,280	38,365	−6.2
Birdwatching (more and ¼ mile from home/vehicle)	11,070	13,476	14,399	13,294	13,339	12,794	14,275	14,152	13,179	13,093	11,589	−18.1
Boardsailing/ windsurfing	**938**	**1118**	**1307**	**1128**	**1617**	**1151**	**1593**	**1324**	**1562**	**1766**	**1737**	**31.2**
Camping (RV)	16,946	16,168	16,517	17,436	15,865	16,698	15,108	14,556	14,663	14,699	15,855	8.9
Camping (with ¼ mile of home/vehicle)	35,618	31,375	33,686	34,338	30,996	32,925	29,982	29,269	28,660	27,742	26,467	−9.6
Canoeing	**9154**	**9797**	**9935**	**10,058**	**10,553**	**9787**	**9839**	**10,153**	**10,044**	**10,236**	**10,046**	**−1.1**
Climbing (sports/ indoor/boulder)	4728	4514	4769	4313	4770	4119	4592	4745	4536	4684	4905	3.4
Climbing (traditional/ ice/mountaineering)	1586	2062	2288	1835	2198	1609	2189	2319	2457	2571	2790	20.3
Fishing (fly)	6071	5756	5941	5568	5478	5683	6012	5878	5842	6089	6456	9.8
Fishing (freshwater/ other)	43,100	43,859	40,331	40,961	38,860	38,868	39,135	37,796	37,821	37,682	38,121	0.9
Fishing (saltwater)	12,466	14,437	13,804	12,303	11,809	11,983	12,017	11,790	11,817	11,975	12,266	4.0
Hiking (day)	29,863	29,965	32,511	32,572	32,496	34,491	34,545	34,378	36,222	37,232	42,128	22.5
Hunting (bow)	3875	3818	3722	4226	3908	4633	4075	4079	4411	4564	4427	8.5
Hunting (handgun)	2525	2595	2873	2276	2709	2671	3553	3198	3091	3400	3512	9.8
Hunting (rifle)	11,242	10,635	10,344	11,114	10,150	10,807	10,164	9792	10,081	10,778	10,797	10.3
Hunting (shotgun)	8987	8545	8731	8490	8062	8678	8174	7894	8220	8438	8271	4.8
Kayak fishing	**n/a**	**n/a**	**n/a**	**n/a**	**1044**	**1201**	**1409**	**1798**	**2074**	**2265**	**2371**	**31.8**
Kayaking (recreational)	**4134**	**5070**	**6240**	**6212**	**6465**	**8229**	**8144**	**8716**	**8855**	**9499**	**10,017**	**14.9**
Kayaking (sea/ touring)	**1136**	**1485**	**1780**	**1771**	**2144**	**2029**	**2446**	**2694**	**2912**	**3079**	**3124**	**16.0**
Kayaking (white water)	**828**	**1207**	**1242**	**1369**	**1842**	**1546**	**1878**	**2146**	**2351**	**2518**	**2552**	**18.9**
Rafting	**3609**	**3786**	**4226**	**4342**	**3869**	**3725**	**3958**	**3915**	**3924**	**4099**	**4095**	**−10.6**
Running/jogging	38,559	41,064	41,130	43,892	49,408	50,713	52,187	54,188	51,127	48,496	47,384	−12.6
Sailing	**3390**	**3786**	**4226**	**4342**	**3869**	**3725**	**3958**	**3915**	**3924**	**4099**	**4095**	**4.6**
Scuba diving	2965	2965	3216	2723	3153	2579	2982	3174	3145	3274	3111	−2.0
Skateboarding	10,130	8429	7807	7352	6808	5827	6627	6350	6582	6436	6442	1.5
Skiing (alpine/ downhill)	n/a	10,362	10,346	10,919	11,504	10,201	8243	8044	8649	9378	9267	12.4
Skiing (cross-country)	n/a	3530	3848	4157	4530	3641	3307	3377	3820	4146	4640	40.3
Skiing (freestyle)	n/a	2817	2711	2950	3647	4318	5357	4007	4564	4465	4640	2.7
Snorkelling	8395	9294	10,296	9358	9305	9318	8011	8700	8752	8874	8717	0.2
Snowboarding	n/a	6841	7159	7421	8196	7579	7351	6418	6785	7676	7602	3.4
Snowshoeing	n/a	2400	2922	3431	3823	4111	4029	3012	3501	3885	3533	−12.3
Stand up paddling	**n/a**	**n/a**	**n/a**	**n/a**	**1050**	**1242**	**1542**	**1993**	**2751**	**3020**	**3220**	**61.6**
Surfing	**2170**	**2206**	**2607**	**2403**	**2767**	**2195**	**2895**	**2658**	**2721**	**2701**	**2793**	**3.0**
Telemarking (downhill)	n/a	1173	1435	1482	1821	2099	2766	1732	2188	2569	2848	3.0
Trail running	4558	4216	4857	4833	5136	5610	6003	6792	7531	8139	8582	26.4

Note: All participation numbers are in thousands (000)

Table 13.3 Trends in number of people of ages 16 and older participating in recreation activities in the USA, 1999–2001 and 2005–2009 for activities with fewer than 15 million participants from 2005 through 2009 (Source: Cordell 2012, p.40)

	Total participants (*millions*)			Percent participating	Percent change
	1994–1995	1999–2001	2005–2009	2005–2009	1999–2001 to 2005–2009
Kayaking	**3.4**	**7.0**	**14.2**	**6.0**	**103.8**
Mountain climbing	9.0	13.2	12.4	5.3	–5.9
Snowboarding	6.1	9.1	12.2	5.2	33.7
Ice skating outdoors	14.2	13.6	12.0	5.1	–11.5
Snowmobiling	9.6	11.3	10.7	4.5	–5.5
Anadromous fishing	11.0	8.6	10.7	4.5	24.1
Sailing	**12.1**	**10.4**	**10.4**	**4.4**	**–0.4**
Caving	9.5	8.8	10.4	4.4	18.4
Rock climbing	7.5	9.0	9.8	4.2	9.5
Rowing	**10.7**	**8.6**	**9.4**	**4.0**	**8.9**
Orienteering	4.8	3.7	6.2	2.6	–21.7
Cross-country skiing	8.8	7.8	6.1	2.6	–21.7
Migratory bird hunting	5.7	4.9	4.9	2.1	–1.1
Ice fishing	4.8	5.7	4.8	2.1	–15.5
Surfing	**2.9**	**3.2**	**4.7**	**2.0**	**46.3**
Snowshoeing	–	4.5	4.1	1.7	–9.4
Scuba diving	–	3.8	3.6	1.5	–5.6
Windsurfing	**2.8**	**1.5**	**1.4**	**0.6**	**–10.1**

Missing data are denoted with "–" and indicate that participation data for that activity were not collected during that time period. Percent change was calculated before rounding

Source: USDA Forest Service (1995) (*n* = 17,217), USDA Forest Service (2001) (*n* = 52,607), and USDA Forest Service (2009) (*n* = 30,398)

Note: The numbers in this table are *annual* participant estimates on data collected during the three time periods
1994–1995 participants based on 201.3 million people of ages 16+ (Woods & Poole Economics, Inc. 2007)
1999–2001 participants based on 214.0 million people of ages 16+ (U.S. Department of Commerce 2000)
2005–2009 participants based on 235.3 million people of ages 16+ (U.S. Department of Commerce 2008)

in the October 2015–October 2016 survey period. For sailing there was an estimated 64,000 participants (0.16% of the population of England) in the October 2005–October 2006 survey period. This had declined to 45,600 (0.10% of the population) by the October 2015–October 2016 survey period. For canoeing there was an estimated 36,500 participants (0.09% of the population of England) in the October 2005–October 2006 survey period. This had increased to 41,900 (0.09% of the population) by the October 2016–October 2066 survey period.

So Table 13.6 shows that the water sports activities of rowing, sailing, and canoeing rank in the lower half of the activities included in the Sport England's APS.

13.3 Environmental Impact

It seems reasonable to examine the impacts of these water sports on the environment in three main areas: physical impacts (wave action, turbidity), biological impacts (on wildlife, fish, invertebrates, plants), chemical impacts (heavy metals, fuel, and oil spillage from engines).

Liddle and Scorgie (1980) reviewed the impacts of recreation on freshwater plants and animals. They made a distinction between water- and shore-based activities and between physical and chemical effects. The impacts of water-based recreation, which result mainly from boating, were considered in terms of wash, turbulence and turbidity, propeller action, direct contact, disturbance to animals,

Table 13.4 Changes in total outdoor recreation participants between 2008 and 2060 across all activities and scenarios (Source: Bowker et al. 2012, p. 28)

Activity[a]	2008 Participants[b] (millions)	2060 Participant range[c] (millions/ [percent])	2060 Average participant change[c] (millions)	2060 Participant range[d] (millions/ [percent])	2060 Average participant change[d] (millions)
Visiting developed sites					
Developed site use—family gatherings, picnicking, developed camping	194	273–346 [42–77]	116	271–339 [40–75]	112
Visiting interpretive sites—nature centres, zoos, historic sites, prehistoric sites	158	231–294 [48–84]	106	231–289 [46–83]	104
Viewing and photographic nature					
Birding—viewing/photographing birds	82	118–149 [42–76]	53	115–144 [40–76]	47
Nature viewing—viewing, photography, study, or nature gathering related to fauna, flora, or natural settings	190	267–338 [42–76]	114	268–333 [41–75]	112
Backcountry activities					
Challenge activities—caving, mountain biking, mountain climbing, rock climbing	25	38–48 [50–86]	19	37–48 [47–90]	18
Equestrian	17	24–31 [44–87]	11	25–35 [50–110]	13
Hiking—day hiking	79	117–150 [50–88]	55	114–143 [45–82]	50
Visiting primitive areas—backpacking, primitive camping, wilderness	91	120–152 [34–65]	47	119–145 [31–60]	42
Motorised activities					
Motorised off-road use	48	62–75 [29–56]	21	62–76 [28–58]	21
Motorised snow use (snowmobiles)	10	10–13 [10–37]	3	4–10 [(56)–6]	(2.5)[e]
Motorised water use	**62**	**87–112 [41–81]**	**40**	**84–111 [35–78]**	**35**
Consumptive					
Hunting—all types of legal hunting	28	30–34 [8–23]	5	29–34 [5–21]	4
Fishing—anadromous, cold-water, saltwater, warm water	73	92–115 [28–56]	33	89–115 [22–58]	30
Non-motorised winter activities					
Downhill skiing, snowboarding	24	38–54 [58–127]	23	36–54 [50–126]	21
Undeveloped skiing—cross-country, snow-shoeing	8	10–13 [32–67]	4	5–10 [(42)–28]	(1)
Non-motorised water					
Swimming, snorkelling, surfing, diving	144	210–268 [47–85]	99	212–266 [47–85]	99
Floating—canoeing, kayaking, rafting	**40**	**52–65 [30–62]**	**20**	**47–62 [18–56]**	**13**

Source: National Survey of Recreation and the Environment (NSRE) 2005–2009, Versions 1 to 4 (January 2005 to April 2009). $n = 24{,}073$ (USDA Forest Service 2009)

[a]Activities are individual or activity composites derived from the NSRE. Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005 to 2009 and the adult (>16) population in the USA during 2008 (235.4 million)

[b]Because of small population and income differences, initial values for 2008 differ across PRA scenarios, thus an average is used for a starting value

[c]Participant range across Resources Planning Act (RPA) scenarios A1B, A2, and B2, without climate considerations

[d]Participant range across RPA scenarios A1B, A2, and B2, each with three selected climate futures

[e]Parentheses denote negative number

Table 13.5 Changes in total outdoor recreation days between 2008 and 2060 across all activities and scenarios (Source: Bowker et al. 2012, p. 29)

Activity[a]	2008 Days[b] (millions)	2060 Days range[c] (millions/ [percent])	2060 Average days change[c] (millions)	2060 Days range[d] (millions/ [percent])	2060 Average days change[d] (millions)
Visiting developed sites					
Developed site use—family gatherings, picnicking, developed camping	2246	3121–3949 [40–74]	1294	3055–3796 [36–69]	1185
Visiting interpretive sites—nature centres, zoos, historic sites, prehistoric sites	1249	1899–2417 [53–91]	952	1935–2435 [55–95]	988
Viewing and photographic nature					
Birding—viewing/photographing birds	8255	11,680–14,322 [40–74]	4859	10,050–13,313 [36–69]	3764
Nature viewing—viewing, photography, study, or nature gathering related to fauna, flora, or natural settings	32,461	41,805–52,835 [31–61]	14,635	41,550–51,288 [28–58]	13,597
Backcountry activities					
Challenge activities—caving, mountain biking, mountain climbing, rock climbing	121	178–219 [49–83]	4859	179–232 [48–92]	89
Equestrian	263	388–503 [49–92]	196	369–482 [40–83]	166
Hiking—day hiking	1835	2901–3682 [59–98]	1470	2825–3541 [54–93]	1366
Visiting primitive areas—backpacking, primitive camping, wilderness	1239	2046	622	1562–1946 [26–57]	519
Motorised activities					
Motorised off-road use	1053	1264–1532 [21–46]	357	1274–1611 [21–53]	385
Motorised snow use (snowmobiles)	69	74–91 [8–33]	16	23–65 [(6)–(67)]	(27)[e]
Motorised water use	**958**	**1304–1806 [37–90]**	**596**	**1245–1763 [30–84]**	**495**
Consumptive					
Hunting—all types of legal hunting	538	506–576 [(5)–8]	14	494–575 [(8)–7]	(8)
Fishing—anadromous, cold-water, saltwater, warm water	1369	1665–2020 [23–46]	514	1602–1958 [17–41]	397
Non-motorised winter activities					
Downhill skiing, snowboarding	178	274–437 [61–150]	179	258–422 [50–146]	165
Undeveloped skiing—cross-country, snow-shoeing	52	69–87 [35–70]	29	28–64 [(45)–25]	(5)
Non-motorised water					
Swimming, snorkelling, surfing, diving	3476	5037–6429 [46–83]	2446	4396–6257 [42–80]	2298
Floating—canoeing, kayaking, rafting	**262**	**338–422 [30–62]**	**128**	**309–409 [18–56]**	**83**

Source: National Survey of Recreation and the Environment (NSRE) 2005–2009, Versions 1 to 4 (January 2005 to April 2009). n = 24,073 (USDA Forest Service 2009)

[a]Activities are individual or activity composites derived from the NSRE. Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005 to 2009 and the adult (>16) population in the USA during 2008 (235.4 million)

[b]Because of small population and income differences, initial values for 2008 differ across PRA scenarios, thus an average is used for a starting value

[c]Participant range across Resources Planning Act (RPA) scenarios A1B, A2, and B2, without climate considerations

[d]Participant range across RPA scenarios A1B, A2, and B2, each with three selected climate futures

[e]Parentheses denote negative number

Table 13.6 Once a week participation in funded sports (16 years and over)—Sport England: Active People Survey 10 (October 2015–September 2016) (Source: https://www.sportengland.org/media/11746/1x30_sport_16plus-factsheet_aps10.pdf)

Sport England NGB 13-17Funded sports	Active People Survey 10 (October 2015–September 2016)	
	%	*n*
Swimming	5.67	2,516,700
Athletics	5.01	2,217,800
Cycling	4.40	1,950,300
Football	4.21	1,844,900
Golf	1.64	729,300
Exercise, movement, & dance	0.98	437,200
Badminton	0.97	425,800
Tennis	0.90	398,100
Equestrian	0.64	282,400
Bowls	1.33	211,900
Squash & racquetball	0.45	199,500
Rugby union	0.46	199,000
Netball	0.42	180,200
Boxing	0.36	159,000
Cricket	0.36	158,500
Basketball	0.35	150,800
Mountaineering	0.25	110,200
Table tennis	0.24	107,100
Angling	0.24	106,200
Snowsport	0.23	99,800
Hockey	0.22	92,700
Weightlifting	0.20	88,100
Rowing	**0.19**	**83,400**
Gymnastics	0.15	65,100
Shooting	0.13	56,600
Sailing	**0.10**	**45,600**
Rugby league	0.10	44,900
Canoeing	**0.09**	**41,900**
Volleyball	0.08	33,800
Archery	0.07	32,400
Taekwondo	0.06	23,900
Judo	0.04	18,900
Rounders	0.03	12,800

Source: Sport England's Active People Survey

pollution from outboard motors and sewage. Those resulting from shore-based activities, such as boat launching and egress (as well as angling discussed in Chap. 15 and swimming), included trampling and associated effects, boat wash erosion, as well as sewage and other chemical impacts.

Aquatic ecosystems, like terrestrial ecosystems, have many parameters that interact to determine water quality. Some of these impacts are direct, occurring on or in the water (Fig. 13.5). Other impacts to water systems are indirect, they come from actions on the shore, land, or watershed adjacent to the water body. Such actions might be due to land use activities like farming, forestry, or industry and lie outside the scope of this chapter.

13.3.1 Physical Impacts of Water Sports

Back in the 1980s, Garrad and Hey (1987) reported that increasing levels of turbidity reported in parts of the Norfolk Broads over the last century had been attributed to algal growth. Their research demonstrated how the resuspension of bed sediments by a single moving boat was possible and how the diurnal variation of boat traffic movement had distinct effects on patterns of suspended sediment concentration and hence turbidity. They concluded that the control of boat speed and frequency therefore had important implications for the management of turbidity levels in the Norfolk Broads, UK. O' Sullivan (1990) examined the effects of recreational usage in the gorges of the Afon Conwy in Snowdonia and noted that it was often difficult to distinguish between the impacts of canoeists and fisherman and other visitors. Spencer (1995) carried out erosion surveys at canoe/kayak access and egress sites on the Afon Llugwy and Afon Tryweryn in Snowdonia and noted a number of examples of erosion which he photographed. Zani (2000) also examined the effect of recreational canoeing on the riparian vegetation of the River Dee in North Wales. He examined sites before and after an organised canoeing event known as the Dee Tour and found on average there to be 70% less vegetation at three popular access and egress sites compared with control sites.

Bradbury et al. (1995) discovered that the wash from high-speed tourist cruise launches caused erosion of the formerly stable banks of

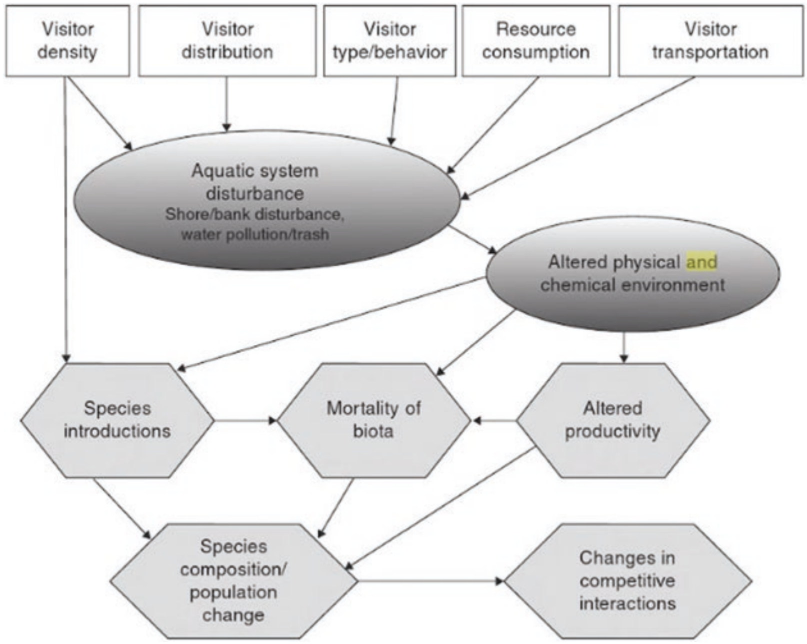

Fig. 13.5 Main impacts of recreation-water resource impacts (after Hammitt et al. 2015; adapted from Monz and Leung 2006)

the lower Gordon River within the Tasmanian Wilderness World Heritage Area. They noted that speed and access restrictions on the operation of commercial cruise vessels had considerably slowed, but not halted erosion, which continued to affect the destabilised banks. Using erosion pins, survey transects, and vegetation quadrats at 48 sites, the mean measured rate of erosion of estuarine banks slowed from 210 to 19 mm/year with the introduction of a 9-knot speed limit. In areas where cruise vessels continued to operate, alluvial banks were eroded at a mean rate of 11 mm/year during the three-year period of the current management regime. Very similar alluvial banks no longer subject to commercial cruise boat traffic eroded at the slower mean rate of 3 mm/year. Sandy levee banks retreated an estimated 10 m maximum during the 10–15 years prior to their study. The mean rate of bank retreat slowed from 112 to 13 mm/year with the exclusion of cruise vessels from the leveed section of the river. Revegetation of the eroded banks was proceeding slowly; however, since the major bank colonisers are very slow growing tree species, they stated that it was likely to be decades until revegetation could contribute substantially to bank stability.

Bishop (2007) showed that waves produced by even low-wash vessels can have a sizeable impact on infaunal assemblages in bottom sediments of sheltered estuaries. Although this impact is widely regarded to be a consequence of wash coarsening sediment grain-size, it may be due to a number of alternative mechanisms which include enhanced turbidity, decreased larval supply, changed resource availability, and/or erosion of animals from the sediment.

With recreational boat usage and ownership in Australia at an all-time high, Ruprecht et al. (2015) investigated the impact that the proliferation of recreational vessels designed and manufactured for the sport of wakeboarding and, more recently, wakesurfing (a popular alternative activity to wakeboarding) were having. Wakeboarding/wakesurfing vessels are designed, through the use and control of ballast and customised trim, to maintain a breaking wave at the optimal operational speed (typically 10 knots for wakesurfing and 19 knots for wakeboarding). Tests were undertaken in a controlled environment (deep water, no currents, controlled boat speeds, repeat runs, etc.) using state-of-the-art measuring equipment, and the results indicated that the wave energy associated with the single maximum wave height for the wakesurf "operating conditions" was approximately four times that of the wakeboard "operating conditions" and twice that of the wakeboard "maximum wave" conditions. Operational wakesurfing was shown to produce significantly different waves to wakeboarding and water skiing. They recommended that these three activities be assessed and managed separately. A common feasible management option would be to restrict those activities to wide parts of the river to allow for natural wave height attenuation. In certain situations, where maximum wave height is a concern, and insufficient distance is available to allow for natural attenuation, management of the sport may result in restricting activities or the implementation of artificial shoreline enhancements (i.e. bank armouring, rip-rap, rock fillets, etc.)

Mujal-Colilles et al. (2017) collected field data in a harbour basin and compared them with analytical formulations for predicting maximum scouring depth due to propeller jets. Spatial data analysis of seven-year biannual bathymetries quantified the evolution of a scouring hole along with the sedimentation process within a harbour basin. The maximum scouring depth was found to be of the order of the propeller diameter with a maximum scouring rate within the first six months of docking manoeuvring.

Gabel et al. (2017) presented a review on the effects of ship-induced waves on the structure, function, and services of aquatic ecosystems based on more than 200 peer-reviewed publications and technical reports. Ship-induced waves act at multiple organisational levels and different spatial and temporal scales. All the abiotic and biotic components of aquatic ecosystems are affected, from the sediment and nutrient budget to the planktonic, benthic, and fish communities. They highlighted how the effects of ship-induced waves cascade through ecosystems and how different effects interact and feed back into the ecosystem finally leading to altered ecosystem services and human health effects.

13.3.2 Biological Impacts of Water Sports

13.3.2.1 Water Quality and Micro-organisms

The Boundary Waters Canoe Area in northern Minnesota is the most heavily used wilderness area in the USA. The majority of its visitors participate in water-based recreational activities that contribute detergents, and sanitary, outboard motor, and solid wastes to the natural chemical budget of the pristine lakes. King and Mace Jr (1974) reported on research which aimed to determine if recreational use caused reduction of water quality in bodies of water located near campsites. Nine parameters of water quality were measured in water near campsites and near unused shorelines for comparison. The parameters measured were dissolved oxygen saturation, temperature, turbidity, hydrogen ion concentration, specific conductivity, nitrate (plus nitrite) concentration, available phosphate concentration, total Kjeldahl nitrogen concentration, and coliform bacteria population. The results show that use of campsites causes highly significant ($\alpha = 0.01$) increases in coliform bacteria populations (Table 13.7) and smaller increases ($\alpha = 0.10$) in available phosphate concentrations in water near the campsites. They suggested that one probable cause of these increases was drainage from the pit toilets located at each campsite.

Fewtrell et al. (1992) noted how there is little quantitative information on the relation between water quality and disease attack rates after recreational activities in freshwater, so they conducted

Table 13.7 Coliform populations for various classes of campsites. University of Minnesota Boundary Waters Canoe Area Campsite Study, 1970 (after Merriam and Smith 1974)

	Number of coliforms/100 ml use categories		
	High	Medium	Low
Campsite	4.61	6.63	5.83
Control	0.28	1.95	4.68
Difference	4.33	4.68	1.15

Note: High-use sites had over 1100 days visitor use; medium-use sites had over 500 days visitor use; low-use sites had less than 300 days total visitor use a prospective cohort study to measure the health effects of white-water and slalom canoeing in two channels with different degrees of microbial contamination. Site A, fed by a lowland river, showed high enterovirus concentrations (arithmetic mean 198 pfu per 10 litre) and moderate faecal coliform concentrations (geometric mean 285/dl); at site B, from an upland impoundment, all samples were free of enteroviruses, and the geometric mean faecal coliform concentration was 22/dl. Between five and seven days after exposure, canoeists using site A had significantly higher incidences of gastrointestinal and upper respiratory symptoms than canoeists using site B or non-exposed controls (spectators). Like seawater bathers, freshwater canoeists can be made ill by sewage contamination. They recommended that the hazard of freshwater may be best measured by counting of viruses rather than bacteria.

Other quantitative risk assessments have estimated health risks of water recreation. One input to risk assessment models is the rate of water ingestion. One published study estimated rates of water ingestion during swimming, but estimates of water ingestion are not available for common limited-contact water recreation activities such as canoeing, fishing, kayaking, motorboating, and rowing. In the summer of 2009, Dorevitch et al. (2011) conducted two related studies to estimate water ingestion during these activities. First, at Chicago area surface waters, survey research methods were utilised to characterise self-reported estimates of water ingestion during canoeing, kayaking, and fishing among 2705 people. Second, at outdoor swimming pools, survey research methods and the analysis of cyanuric acid, a tracer of swimming pool water, were used to characterise water ingestion among 662 people who engaged in a variety of full-contact and limited-contact recreational activities. Data from the swimming study was used to derive translation factors that quantify the volume of self-reported estimates. At surface waters, less than 2% of canoeists and kayakers reported swallowing a teaspoon or more and 0.5% reported swallowing a mouthful or more. Swimmers in a pool were about 25–50 times more likely to report swallowing a teaspoon of water compared to those who participate in limited-contact recreational activities on surface waters. Mean and upper confidence estimates of water ingestion during limited-contact recreation on surface waters are about 3–4 ml and 10–15 ml, respectively. These estimates of water ingestion rates may be useful in modelling the health risks of water recreation.

Phillip et al. (2009) conducted a study to determine the possible influence of recreation on microbiological water quality of a tropical stream. Microbiological water quality was measured at several recreational sites along the stream, and a separate experiment was conducted to look at the effect of sediment resuspension on microbiological water quality. Microbiological quality of the water in the stream was generally poor and varied widely with faecal coliform and *Escherichia coli* levels ranging from 1 to >16,000 and 14 to 9615 organisms 100 ml^{-1}, respectively. Levels of faecal coliforms were higher in the wet (median = 700 organisms 100 ml^{-1}) than the dry (median = 500 organisms 100 ml^{-1}) season while the reverse was true for *E. coli* (median = 300 and 220 organisms 100 ml^{-1} in the wet and dry seasons, respectively). Recreational activity resulted in reduced water quality: sites with recreation had poorer water quality than those without; water quality was generally poorer when there were high numbers of recreational users. Wading resulted in a fourfold increase in mean *E. coli* densities and a threefold increase in total suspended sediments in the overlying water suggesting that the increases were due to suspension of bacteria from the sediments. They concluded that water quality monitoring methodology for assessing recreational water quality should be amended to factor in the effects of wading since environmental strains of bacteria can be pathogenic and thus represent a human health threat.

DeFlorio-Barker et al. (2017) estimated the costs of sporadic gastrointestinal illness associated with surface water recreation. They characterised the disease burden attributable to water recreation using data from two cohort studies using a cost of illness (COI) approach and estimated the largest drivers of the disease burden of water recreation. Comparing data which evaluated swimming and wading in marine and freshwater beaches in six US states, with data which evaluated illness after incidental-contact recreation (boating, canoeing, fishing, kayaking, and rowing) on waterways in the Chicago area, they estimated the cost per case of gastrointestinal illness and costs attributable to water recreation. Data on health care and medication utilisation and missed days of work or leisure were collected and combined with cost data to construct measures of COI. Depending on different assumptions, the cost of gastrointestinal symptoms which were attributable to water recreation were estimated to be $1220 for incidental-contact recreation (range $338–$1681) and $1676 for swimming/wading (range $425–2743) per 1000 recreational users. Lost productivity was found to be a major driver of the estimated COI, accounting for up to 90% of total costs. These estimates suggested that gastrointestinal illness attributed to surface water recreation at urban waterways, lakes, and coastal marine beaches was responsible for costs that should be accounted for when considering the monetary impact of efforts to improve water quality. The COI provides more information than the frequency of illness, as it takes into account disease incidence, health-care utilisation, and lost productivity.

13.3.2.2 Impacts on Plants and the Spread of Invasive Species

Liddle and Scorgie (1980) developed a useful flow chart of the impacts of boats on plants (Fig. 13.6). They saw three main ways in which boats impact plants: by propeller action, from wash, and by direct contact.

The wash created by motorised craft can cause considerable erosion of plant roots. Haslam (1978) investigated the susceptibility of a number of plants to erosion by directing a horizontal jet of water from upstream onto the soil at the base of the plants, and the time taken for the plants to be eroded was noted. On this basis plants were placed into four groups. One of the most resistant, the yellow waterlily (*Nuphar lutea*), has smaller leaves in faster-flowing waters.

In many parts of the world, the spread of invasive aquatic plant species by boats is a major

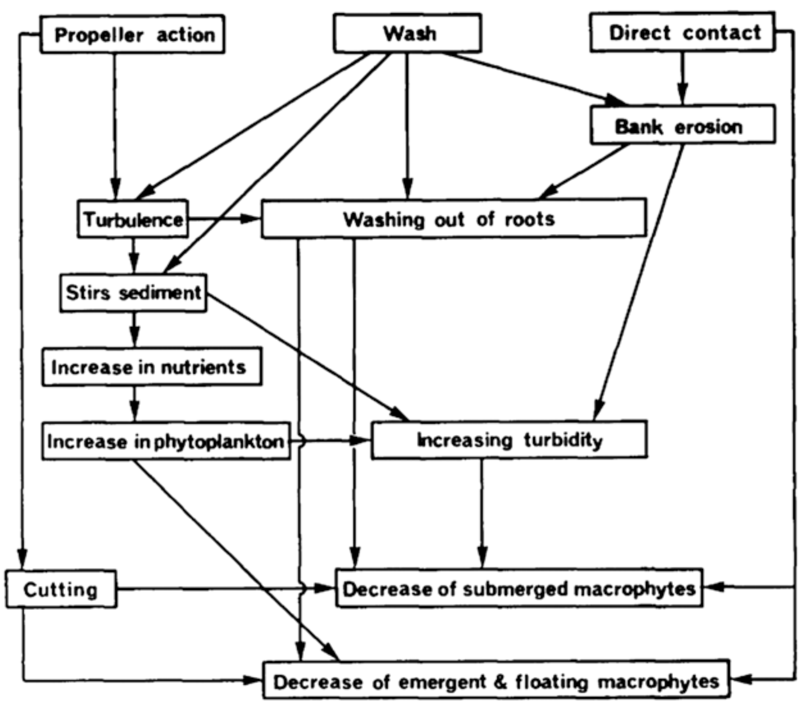

Fig. 13.6 The impacts of boats on plants (after Liddle and Scorgie 1980, p. 185)

problem and is among the most important threats to biodiversity worldwide. For example, aquatic ecosystems in South Africa are prone to invasion by several invasive alien aquatic weeds, most notably, *Eichhornia crassipes* (Mart.) *Solms-Laub*. (*Pontederiaceae*) (water hyacinth), *Pistia stratiotes L.* (*Araceae*) (water lettuce), *Salvinia molesta D.S. Mitch.* (*Salviniaceae*) (salvinia), *Myriophyllum aquaticum (Vell. Conc.) Verd.* (parrot's feather), and *Azolla filiculoides Lam.* (*Azollaceae*) (red water fern). Hill and Coetzee (2017) reviewed the biological control programme on waterweeds in South Africa and found that there had been significant reductions in the extent of invasions and a return on biodiversity and socio-economic benefits through the control programme. These studies provide justification for the control of widespread and emerging freshwater invasive alien aquatic weeds in South Africa. The long-term management of alien aquatic vegetation relies on the correct implementation of biological control for those species already in the country and the prevention of other species entering South Africa.

Eurasian watermilfoil, an aquatic invasive weed, occurs at a number of sites in western Nevada and northeastern California, including Lake Tahoe. Because Eurasian watermilfoil is easily spread by fragments, transport on boats and boating equipment plays a key role in contaminating new water bodies. This is an important means of the potential spread of this weed throughout key recreational and agricultural areas surrounding Lake Tahoe. Unless the weed is controlled, significant alterations of aquatic ecosystems, with associated degradation of natural resources and economic damages to human uses of those resources, may occur. Eiswerth et al. (2000) used an economic valuation approach known as benefits transfer to estimate the value of a portion of the recreational service flows that society currently enjoys in the Truckee River watershed below Lake Tahoe. The lower-bound estimates of baseline water-based recreation value at a subset of sites in the watershed range from \$30 to \$45 million/year. Impacts from the continued spread of Eurasian watermilfoil in the watershed could be significant; for example, even a 1% decrease in recreation values would correspond to roughly \$500,000/year as a lower bound.

Murphy and Eaton (1983) conducted quantitative surveys of plant growth in British Cruising and Remainder Canals which showed significant associations between community composition, abundance of aquatic macrophytes, and pleasure-boat traffic. They found evidence for a "critical" traffic range, about 2000–4000 movements ha^{-1} m $depth^{-1}$ $year^{-1}$ (4 $weeks)^{-1}$ (my) reducing submerged macrophyte standing crop, perhaps by maintaining high daytime water turbidity during the summer months as there were significant associations between boat traffic density, water turbidity, and summer submerged crop. The seasonal distribution of pleasure-boat traffic appeared to be an important influence on submerged macrophyte community abundance. They noted that the course of macrophyte community development may be largely determined by the stage in the growth season at which traffic in the range 300–600 my is attained. Relationships between the abundance of emergent plants and boat traffic were weaker, and there was no significant association with water turbidity. In 1977 approximately 50% of the canal system carried low pleasure-boat traffic density (<2000 my), 24% had traffic within the critical range (2000–4000 my), and 26% had heavy traffic (>4000 my).

Walsh et al. (2016) evaluated the economic impacts of an invasive species that cascaded through a food web to cause substantial declines in water clarity, a valued ecosystem service. The predatory zooplankton, the spiny water flea (*Bythotrephes longimanus*), invaded the Laurentian Great Lakes in the 1980s and then subsequently spread to inland lakes, including Lake Mendota (Wisconsin), in 2009. In Lake Mendota, *Bythotrephes* reached unparalleled densities compared with in other lakes, decreasing biomass of the grazer *Daphnia pulicaria* and causing a decline in water clarity of nearly 1 m. Time series modeling revealed that the loss in water clarity, valued at US\$140 million (US\$640 per household), could be reversed by a 71% reduction in phosphorus loading. A phosphorus reduction of this magnitude was estimated to cost between US\$86.5 million and US\$163 million

(US$430–US$810 per household). Estimates of the economic effects of Great Lakes invasive species may increase considerably if cases of secondary invasions into inland lakes, such as Lake Mendota, are included. Furthermore, they concluded that such extreme cases of economic damages called for increased investment in the prevention and control of invasive species to better maximise the economic benefits of such programmes.

De Ventura et al. (2016) examined how recreational boats that are transported overland could contribute to the dispersal of invasive zebra mussels among lakes in Switzerland. Using a questionnaire sent to registered boat owners, they surveyed properties of transported boats and collected information on self-reported mussel fouling and transport activities of boat owners. They also sampled boat hulls at launching ramps and harbours for biofouling invertebrates. Boats that were kept seasonally or year-round in water were found to have high vector potential with mussel fouling rates of more than 40%. However, only about 6% of boats belonging to these groups were transported overland to other water bodies. Considering that approximately 100,000 recreational boats are registered in Switzerland, they estimated that every year around 1400 boats fouled with mussels were transported overland. Such boats pose a high risk of distributing zebra mussels between water bodies. Their results suggested that there is a considerable risk that recreational boats may spread new fouling species to all navigable water bodies within the study area and speculated that one such species could be the quagga mussel, which has not yet invaded lakes in Switzerland. However, their study has identified the group of high-risk boats so that possible control measures could be targeted at this relatively small group of boat owners.

13.3.2.3 Disturbance to Wildlife

Water-based recreation can result in disturbance to wildlife. Perhaps the best studied group about which the effects of disturbance have been observed is birds. Hockin et al. (1992) noted that human-induced disturbance can have a significant negative effect on breeding success by causing nest abandonment and increased predation. Outside the breeding season, recreation (particularly power-boating, sailing, and coarse fishing on wetlands) reduces the use of sites by birds. Compensatory feeding at night by some species can probably recoup some of the energy losses caused by disturbance. Mosisch and Arthington (1998) presented some data to support this (Table 13.8).

Steven et al. (2011) conducted a review of the impacts of nature-based recreation on birds. Their review of the recreation ecology literature published in English language academic journals identified 69 papers from 1978 to 2010 that examined the effect of these activities on birds. Sixty-one of the papers (88%) found negative impacts, including changes in bird physiology (all 11 papers), immediate behaviour (37 out of 41 papers), as well as changes in abundance (28 out of 33 papers) and reproductive success (28 out of 33 papers). Previous studies are concentrated in a few countries (USA, England, Argentina, and New Zealand), mostly in cool temperate or temperate climatic zones, often in shoreline or wetland habitats, and mostly on insectivore, carnivore, and crustaceovore/molluscivore foraging guilds. They found limited research in some regions with both high bird diversity and nature-based recreation such as mainland Australia, Central America, Asia, and Africa and for popular activities such as mountain bike riding and horse riding. It was clear that non-motorised nature-based recreation has negative impacts on a diversity of birds from a range of habitats in different climatic zones and regions of the world.

The edges of propellers can act like a set of rotating knives. Liddle and Scorgie (1980)

Table 13.8 Breeding densities (pairs/10 km channel) of three common species of English waterbirds in used and disused canals (adapted from Mosisch and Arthington 1998)

Species	Disused canal	Used canal
Little grebe (*Tachybaptus ruficollis*)	5.1	0.2
Coot (*Fulica atra*)	4.7	2.5
Moorhen (*Gallinula chloropus*)	37.8	22.5

reported that a boat with an outboard motor driven through a patch of yellow water lily (*Nuphar lutea*) cut through the petioles, leaving a very jagged end. On a 50 m run, 15 leaves were detached and many more were overturned. Other studies have found that used in shallow water, propellers can cut plants right out of a mud substrate and remove sediment, which can lead to increased turbidity. More recently, Whitfield and Becker (2014) conducted a detailed review of the impacts of recreational motorboats on fishes. They reported that some fish species do not appear to respond behaviourally to the presence of powered outboard engines, for example, lake trout (*Salvelinus namaycush*) in a small Canadian lake did not respond to boat traffic, even during detailed manual tracking of individual fish. However, the passage of boats has been shown to break up fish schools and result in increased energy expenditure as they attempt to move away from the disturbance. Manipulative work examining nest guarding behaviour of longear sunfish found that passing boats caused fish to leave their nests for longer periods than during control times. A recent study on the effects of passing motorboats on the abundance of different sized fish within the main channel of a South African estuary revealed that the 100–300 mm and >500 size classes had no change in their abundance following the passage of boats (Becker et al. 2013). However, the mid-sized fishes (301–500 mm) decreased in abundance, a displacement which was attributed to a number of factors, including noise, bubbles, and the approaching boat itself.

Disturbance effects of motorboats on fishes can be linked to several factors (Fig. 13.7), including noise levels (Slabbekoorn et al. 2010). Since fish have sensitive auditory organs, anthropogenic noise has the potential to cause physiological and behavioural responses (Purser and Radford 2011). In situ recording of powerboat noise spectra indicate that outboard sounds can be detected by species such as cyprinids at a distance of hundreds of metres (Amoser et al. 2004). Noise from boats may also increase fish stress levels or even have a direct impact on the

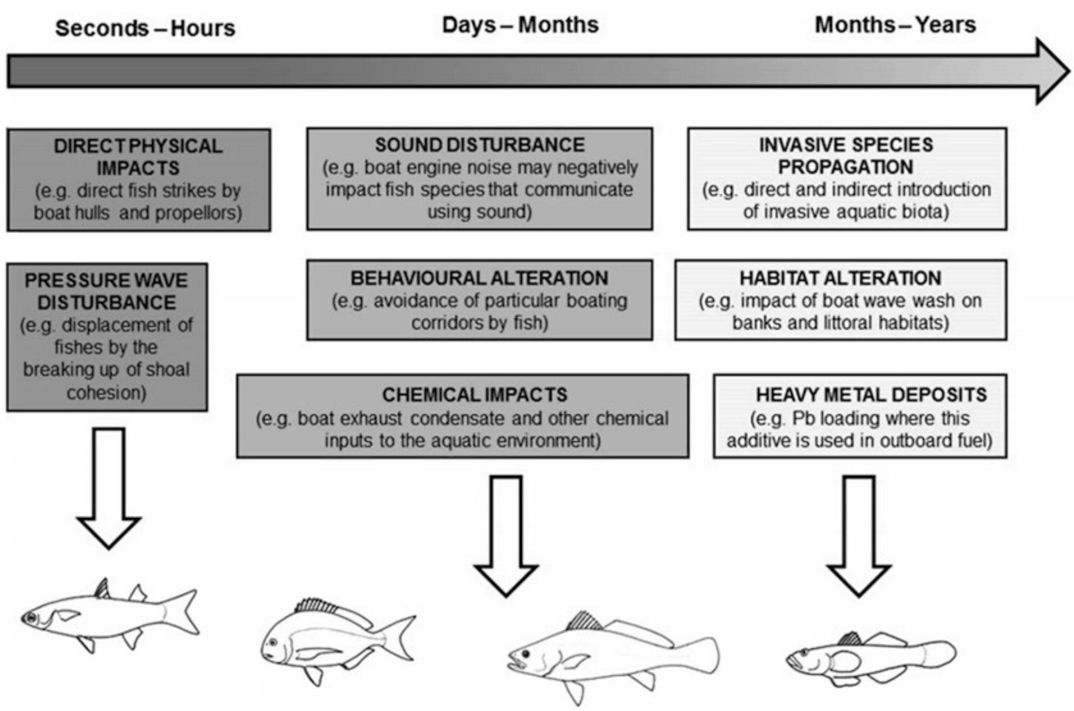

Fig. 13.7 Likely influences and impacts of powerboating activities on fishes and their habitats and the likely time frame over which the impacts may occur (after Whitfield and Becker 2014, p. 25)

breeding behaviour of certain fish. Boat noise has also been shown to adversely affect the territorial behaviour of certain fish species which uses sound production as an effective tool for territorial defence and nest caring.

To date there seems to be very limited work conducted on the environmental effects of PWC or "jet skis," and this seems to be an area for future research. While the air noise pollution of PWC is often complained about by the public (Blomburg et al. 2003), noise emitted by these craft in the water may also be of concern (Erbe 2013). Also, PWC riders tend to change speed and direction far more frequently than those driving typical recreational boats, thus giving rise to unpredictable changes in sound pitch and volume as well as craft direction. Additionally the hull of PWC tends to strike the water surface harder and with greater frequency than typical motorboats, all of which is likely to cause more confusion in nearby fish schools.

13.3.3 Chemical Impacts of Water Sports

13.3.3.1 Heavy Metals

Heavy metal inputs to aquatic environments became a major issue following the industrial revolution, and in the modern era, these pollutants can come from a variety of sources, including boats. In terms of recreational boating, in the recent past, the major sources of heavy metals were antifouling paints and boat exhaust emissions. Secondly, resuspension of sediment bound metals by boat wake, and direct sediment disturbance by boat engine operations in shallow water, have accentuated the problem. Fortunately, considerable progress has been made in reducing toxic metals from paints and lead from petroleum products, thus reducing pollution from these sources. Increasing lead levels in lakes, rivers, and estuaries are perhaps one of the most obvious potential indicators of environmental pollution by outboard motors, particularly where lead is used as an additive to the fuel. Lead in the aquatic environment from exhaust waste is most likely to occur in a relatively insoluble form with lead accumulating in the sediments and being potentially absorbed by certain benthic biota. Boat traffic can also result in the resuspension of heavy metals from polluted sediments. For example, boat traffic in the Deûle River in northern France has been directly linked to the resuspension of sedimentary particles that significantly increased lead and zinc into the overlying water (Superville et al. 2014).

Elevated copper levels in Lake Texoma water were attributed to antifouling-based paint used on boats and high copper levels at specific locations in marinas around the lake appeared to be associated with recreational boat repair activities (An and Kampbell 2003). Leaching of tributyltin-containing antifouling paints used on boats into coastal waters is a major problem for certain invertebrate species (Bhosle et al. 2004) and the enzyme system activities of certain fish. Molluscs appear to be most affected by tributyltin and its degradation products, with fish having low levels of contamination. However, because fish invertebrate prey is negatively affected by tributyltin, it is likely that fish stocks will also be impacted. Fortunately, legislation in many countries has seen these toxic paints being replaced by more environmentally acceptable alternatives.

Eklund and Watermann (2018) used a handheld X-ray fluorescence (XRF) analyser specially calibrated for measurements of metals on plastic boat hulls on leisure boats in Denmark (DK), Finland (FI), and Germany (DE). The results on tin and copper are presented as μg metal/cm^2 and were compared with published data from different parts of Sweden, that is, boats in freshwater, brackish water, and saltwater. The results showed that tin with mean values >50 μg Sn/cm^2 is still found on 42%, 24%, and 23% of the boats in DK, FI, and DE, respectively. The corresponding percentages based on median values are 38%, 22%, and 18% for DK, FI, and DE, respectively. The variation among boats is high with a maximum mean value of 2000 μg Sn/cm^2. As comparison, one layer of an old Tributyltin (TBT) antifouling paint Hempels Hard Racing Superior corresponds to 300 μg Sn/cm^2. The percentage of boats with tin >400 µg Sn/cm^2 content based on mean values were 10% in DK, 5% in FI, and 1% in DE. The corresponding median values were 9%, 6%, and 1% for DK, FI, and DE, respectively. Copper, >100 µg Cu/cm^2, was detected on all measured boats in DK and in DE and on all but 3% of the FI boats. One layer of Hempels Mille Xtra corresponds to~ 4000 µg Cu/cm^2. The recommendation on the can is to apply two layers. The proportion of boats with higher mean copper values than 8000 µg Cu/cm^2 was 51, 56, and 61 for boats in DK, FI, and DE, respectively. The proportion based on median values >8000 µg Cu/cm^2 was 50%, 54%, and 61% for DK, FI, and DE, respectively. The conclusion was that many leisure boats around the Baltic Sea still display or possess antifouling paints containing organotin compounds and that more than half of the boats have more copper than needed for one boat season according to the paint producers. Much of these known toxic compounds will probably be released into the environment and harm the biota.

13.3.3.2 Motorboat Engine Products and Bi-products

Motorboats are usually powered by either diesel or a petroleum and oil-based mixture, both of which are sometimes accidentally spilt into waterways when filling up tanks or servicing engines close to the water. In addition, both types of fuel emit exhaust fumes into or onto the water when the motorboat is underway which can affect fish eggs, larvae, and juveniles, especially in surface waters. Diesel is an important fuel used by both small and large boats in coastal areas and has the potential to influence gene expression in fishes (Mattos et al. 2010). Similarly, petroleum contamination of the surrounding water by small boats was found to negatively influence the health of winter flounder (*Pleuronectes americanus*) in Placentia Bay, Newfoundland (Khan 2003). Accidental spillage of motorboat fuel directly into aquatic ecosystems is a reality and will always remain a water pollution risk.

Laboratory tests conducted in 1960 by English et al. (1963) showed that bluegill sunfish were killed when outboard fuel consumption reached 530 L per million litres of water. However, fish flesh could be tainted by outboard motor exhaust wastes at much lower levels. These tests showed that 90% of persons in a taste panel noted objectionable flavour in fish exposed to cumulative fuel consumption levels of 2.8 L per million litres of water. Lüdermann (1968) found that detrimental changes in the flavour of the flesh of freshwater fishes exposed to the exhaust emissions of outboard motors disappeared after a few days of the fish living in clean freshwater. Carbon monoxide was attributed to fish kills near an outboard testing facility on the Fox River and the suggestion made that such events could to be exacerbated by low river flows and high temperatures (Kempinger et al. 1998). This indicates that there may be potential for carbon monoxide poisoning in areas with very high boat traffic and low flushing rates.

Table 13.9 summarises the major impacts of recreational motorboat activities.

Professor Joy Tivy of Glasgow University (Tivy 1980) wrote a very detailed report on the effect of recreation on freshwater lochs and reservoirs in Scotland which was commissioned and published by the Countryside Commission for Scotland. This comprehensive report examined all aspects of recreational impact on and around the water.

13.4 Management and Education

Future management of water-based recreation must take account of the predicted future increases in participation numbers (as we saw in Sect. 13.2) and climate change.

13.4.1 Managing Physical Impacts

O' Sullivan (1990) examined the effects of recreational usage in the gorges of the Afon Conwy in Snowdonia. He noted that his observations at the time did not present a cause for ecological concern in the gorges and concluded that "positive management plans arrived at through essential dialogue between recreationalists and conservationists are

Table 13.9 Summary of the major findings relating to recreational motorboat activities (adapted from Whitfield and Becker 2014)

Motorboat traffic and direct hits	Evidence of direct hits by boats. Very few studies have quantified fish strikes by boats at various speeds or the fish sizes that are affected. This is an area needing further research
Motorboat traffic and fish behaviour	The effect of motorboat traffic on the behaviour of fish is probably the most studied aspect of boat impacts on fish. Noise emitted from engines may increase stress levels in fishes, and underwater noise has also been linked to disruption in the reproductive behaviour of certain fishes. Noise has been found to influence all fish life history stages, including the larvae. Most studies have been conducted in laboratories, but recent examples from field based studies have provided real data for the testing of hypotheses. Further research is required on fish size-related responses to boat movements, as well as which species are most negatively affected by boat traffic
Heavy metals	Sources of heavy metals in aquatic ecosystems arising from boats include antifouling paints and exhaust emissions, as well as the resuspension of contaminated sediments by boat propeller action and wave wakes. More research is needed to link levels of boating activity to Pb and other metal concentrations in the aquatic environment
Motorboat bi-products	Engine exhaust is the most prominent bi-product of motorboats. Diesel can influence gene expression in fish, while multiple studies have found that other petroleum-based products can adversely affect the health of fish. Carbon monoxide poisoning has been linked to fish kills, and this may be a particular threat in systems with high boat traffic and low flushing rates
Invasive species propagation	Transport of invasive fish species overland from one water body to another is a major issue, with this often being done deliberately. However the inadvertent transport of fish diseases and parasites on/in boats and associated equipment is a topic which has not received research attention and is in need of urgent investigation
Boat infrastructure	Infrastructure which facilitates boating activities such as piers, moorings, ramps, and marinas can impact fish assemblages. Removal of natural habitat to construct infrastructure has the greatest impact, with fish and invertebrate assemblages on man-made structures rarely the same as those found in natural habitats. Research has also been conducted on the negative effects of mooring sites and anchoring chains on seagrass beds. The use of swing mooring has been shown to greatly reduce these impacts
Impacts on aquatic habitats	Moving boats can impact aquatic habitats by increasing turbidity, eroding banks with wave wash, and scouring aquatic macrophyte habitats with boat propellers. Invertebrates in seagrass exposed to boating activity have been found to have lower diversity than control sites, which can have important implications for fish productivity wave wash from boats can be mediated by restricting the speed of boat traffic in sensitive areas

necessary now and are likely to be required in future" (p. 81). Spencer (1995) carried out erosion surveys at canoe/kayak access and egress sites on the Afon Llugwy and Afon Tryweryn in Snowdonia and noted a number of examples of erosion which he photographed and undertook interviews with canoeists who exhibited "negative attitudes towards the environment" (p. iii) and concluded that a code of conduct was needed.

Earlier in this chapter, we reported on the study by Bradbury et al. (1995) which showed that the wash from high-speed tourist cruise launches caused erosion of the formerly stable banks of the lower Gordon River within the Tasmanian Wilderness World Heritage Area. They noted how speed and access restrictions on the operation of commercial cruise vessels had considerably slowed, but not halted erosion, which continued to affect the destabilised banks. Revegetation of the eroded banks was proceeding slowly; however, since the major bank colonisers are very slow growing tree species, they stated that it was likely to be decades until revegetation could contribute substantially to bank stability.

Bonham (1980) reported the results of field trials in the UK which showed that beds of *Phragmites australis*, *Scirpus lacustris*, *Typha angustifolia*, and *Acorus calamus* attenuated ship waves from motorboat wash. They concluded that under suitable conditions of depth, vegetation density and a bed slope of 1 in 4, a bed of any of these species 2 m wide would dissipate almost two thirds of shipwave energy. They suggested that beds be re-established with mixed emergent species in both mixed bed and fen and Broadland Rivers with high motorboat usage would give bank protection and also provide a scarce natural habitat.

13.4.2 Managing Biological/Water Quality Impacts

Sharp et al. (2017) noted how aquatic invasive species (AIS) present a great challenge to ecosystems around the globe, and controlling AIS becomes increasingly difficult when the potential vectors are related to recreational activities. They claimed that an approach combining education and outreach efforts to control AIS may be the best course of action. They therefore designed a survey to measure public perceptions, knowledge of, and attitudes towards AIS, as well as public support for various management actions. Surveys were administered during the summer of 2013 at two boat launches where one launch had active outreach the previous summer and one that did not. A total of 400 surveys were completed with a response rate of 89%. There was support for most proposed management options, and respondents understood the urgency of managing AIS. There was a difference between the launches in how people responded, highlighting that educational programming may need to be tailored for specific recreational uses and recreational settings.

Breen et al. (2017) collected water quality data from Ireland and carried out an on-site survey of waterway users to evaluate how water quality affected trip days demanded for recreational activities. Water quality measures employed in the analysis included Water Framework Directive (WFD) ecological status as well as several physiochemical measures. The analysis found some evidence that higher levels of recreational demand occur at sites with the highest quality metric measures. However, in many of the estimated models, there was no statistical association between the water quality metric (e.g. WFD status, Biological Oxygen Demand (BOD), ammonia, etc.) and the duration of the recreational trip. As most sites considered in the analysis had relatively high levels of water quality, this result possibly suggested that above an unspecified threshold level that water quality is not a significant determinant of recreational trip duration. Model estimates also revealed a relatively high valuation among participants for water-based recreational activity with an estimate of mean willingness to pay equivalent to €204/day.

Figure 8.8 (Chap. 8) shows visitor signs alerting water users to the spread of invasive species.

Hussner et al. (2017) noted how introduced invasive alien aquatic plants (IAAPs) threaten ecosystems due to their excessive growth and have both ecological and economic impacts. To minimise these impacts, effective management of IAAPs is required according to national or international laws and regulations (e.g. the new EU regulation 1143/2014). Prevention of the introduction of IAAPs is considered the most cost-effective management option. If/when prevention fails, early detection and rapid response increase the likelihood of eradication of the IAAPs and can minimise ongoing management costs. For effective weed control (eradication and/or reduction), a variety of management techniques may be used. The goal or outcome of management interventions may vary depending on the site (i.e. a single waterbody or a region with multiple waterbodies) and the feasibility of achieving the goal with the tools or methods available. Broadly defined management goals fall into three different categories of containment, reduction or nuisance control, and eradication. Management of IAAP utilises a range of control methods, either alone or in combination, to achieve a successful outcome. Hussner et al. reviewed the biological, chemical, and mechanical control methods for IAAPs, with a focus on the temperate and subtropical regions of the world and provided a management diagram illustrating the relationships between the state of the ecosystem, the management goals, outcomes, and tools.

13.4.3 Managing for Climate Change

There have been much interest in the effect that climate change in future might have on water resources in many parts of the world (e.g. Arnell

1998; La Jeunesse et al. 2016; Wang et al. 2016) but less specifically on how and whether water-based recreation will be affected and how it will need to adapt.

Faccioli et al. (2015) noted that climate change will further exacerbate wetland deterioration, especially in the Mediterranean region. On the one side, they claimed that it will accelerate the decline in the populations and species of plants and animals, resulting in an impoverishment of biological abundance. On the other hand, it will also promote biotic homogenisation, resulting in a loss of species' diversity. In this context, they stated that different climate change adaptation policies could be designed: those oriented to recovering species' abundance and those aimed at restoring species' diversity.

Based on the awareness that knowledge about visitors' preferences is crucial to better inform policy makers and secure wetlands' public use and conservation, Faccioli et al. assessed the recreational benefits of different adaptation options through a choice experiment study carried out in S'Albufera wetland (Mallorca). Their results showed that visitors display positive preferences for an increase in both species' abundance and diversity, although they assigned a higher value to the latter, thus suggesting a higher social acceptability of policies pursuing wetlands' differentiation. This finding acquires special relevance not only for adaptation management in wetlands but also for tourism planning, as most visitors to S'Albufera are tourists. Thus, given the growing competition to attract visitors and the increasing demand for high environmental quality and unique experiences, promoting wetlands' differentiation could be a good strategy to gain competitive advantage over other wetland areas and tourism destinations.

13.4.4 Concluding Comments

Clearly there are a number of examples of research which indicates that water-based recreation can have damaging effects on the environment. These can be physical such as in-stream macrophytes being cut by outboard engine propellers, wave wash accelerating bank erosion, and scouring the bed thereby increasing turbidity. Biological impacts include the spread of invasive species, the contamination of water-bodies by sewage and other products brought in by recreationists and disturbance to wildlife. The third general set of impacts is concerned with the chemical changes to water brought about by antifouling paints on the hulls of recreational craft and spills and leakage of oils and fuels.

It is probably reasonable to conclude therefore that the environmental impacts of motorised recreation craft are far greater than for non-motorised ones.

Conclusions

1. The term water sports includes a wide range of activities both in the water and on the water surface. Chapter 14 dealt with some of the underwater activities: scuba diving and snorkelling. This chapter focussed on some of the more popular water recreational activities which take place on the water surface, and these can be divided into the non-motorised (canoeing, kayaking, rafting, rowing, sailing, surfing, and windsurfing) and motorised (jet skiing, motorboating/powerboating, water skiing).
2. The Outdoor Foundation (2017) survey for the USA provided data for eight water sport disciplines. The rank order in terms of the greatest number of participants in 2016 was:
   - *Canoeing*—10,046,000 participants in 2016 and a −1.1% decrease over the previous three years.
   - *Kayaking* (recreational)—10,017,000 participants in 2016 and a three-year increase of 14.9%.
   - *Sailing*—4,095,000 participants in 2016 and a three-year increase of 4.6%.

- *Rafting*—3,428,000 participants in 2016 and a three-year decrease of −10.6%.
- *Stand-up paddling*—3,220,000 participants in 2016 and a massive three-year increase of 61.6%.
- *Kayaking* (sea/touring)—3,124,000 participants in 2016 and a three-year increase of 16.0%.
- *Surfing*—2,793,000 participants in 2016 and a three-year increase of 5.1%.
- *Kayaking (white water)*—2,552,000 participants in 2016 and a three-year increase of 18.9%.
- *Boardsailing/windsurfing*—1,737,000 participants in 2016 and a three-year increase of 31.2%.

If we total all three kayaking disciplines, there were a total of 15,693,000 participants in 2016, making it the most popular of the disciplines in the survey. Stand-up paddling showed by far the greatest three-year increase of 61.6%.

3. Bowker et al. (2012) projected changes in total outdoor recreation participants between 2008 and 2060. There was an estimated 62 million participants in 2008 taking part in motorised water activities (motorboating, water skiing, PWC), and this was predicted to become 87–112 million by 2060. For non-motorised floating water activities (canoeing, kayaking, and rafting), there was an estimated 40 million participants in 2008 taking part, and this was predicted to increase to 52–65 million by 2060. So water-based recreation is projected to increase over the next four decades at least.
4. Water-based recreation can have damaging effects on the environment. Physical impacts include damage to in-stream macrophytes by cutting by outboard engine propellers, wave wash accelerating bank erosion, and scouring the bed thereby increasing turbidity.
5. Biological impacts of water-based recreation include the spread of invasive species, the contamination of waterbodies by sewage and other products brought in by recreationists, and disturbance to wildlife.
6. Water-based recreation can cause chemical changes to water brought about by antifouling paints on the hulls of recreational craft and spills and leakage of oils and fuels.
7. It is probably reasonable to conclude therefore, that the environmental impacts of motorised recreation craft are far greater than for non-motorised ones.
8. There are numerous examples of how these impacts can be managed. For example, controlling the speeds at which watercraft move reduces the impact of wave action and its effect on bank erosion. Planting certain reed species on gently sloping banks can ameliorate the effects of wave action generated by boats. Educating boat users (e.g. by placing information signs at water access points) has been shown to control the spread of invasive species. Changes to the law regarding the use of certain antifouling paints used to protect boat hulls have resulted in reductions in heavy metal concentrations in water and improved water quality.

References

Amoser, S., Wysocki, L. E., & Ladich, F. (2004). Noise emission during the first powerboat race in an alpine lake and potential impact on fish communities. *The Journal of the Acoustical Society of America, 116*, 3797–3798.

An, Y. J., & Kampbell, D. H. (2003). Total, dissolved, and bioavailable metals at Lake Texoma marinas. *Environmental Pollution, 122*(2), 253–259.

Arnell, N. W. (1998). Climate change and water resources in Britain. *Climatic Change, 39*(1), 83–110.

Becker, A., Whitfield, A. K., Cowley, P. D., Järnegren, J., & Næsje, T. F. (2013). Does boat traffic cause displacement in estuarine fish? *Marine Pollution Bulletin, 75*, 168–173.

Bhosle, N. B., Garg, A., Jadhav, S., Harjee, R., Sawant, S. S., Venkat, K., et al. (2004). Butyltins in water, biofilm, animals and sediments of the west coast of India. *Chemosphere, 57*(8), 897–907.

Bishop, M. J. (2007). Impacts of boat-generated waves on macroinfauna: Towards a mechanistic understanding. *Journal of Experimental Marine Biology and Ecology, 343*(2), 187–196.

Blomburg, L. D., Schomer, P. D., & Wood, E. W. (2003). The interest of the general public in a national noise policy. *Noise Control Engineering Journal, 51*(3), 172–175.

Bonham, A. J. (1980). *Bank Protection Using Emergent Plants against Boat Wash in Rivers and Canals*. Report, No. IT 206. Wallingford: Hydraulics Research Station.

Bowker, J. M., Askew, A. E., Cordell, H. K., Betz, C. J., Zarnoch, S. J., & Seymour, L. (2012). *Outdoor Recreation Participation in the United States—Projections to 2060: A Technical Document Supporting the Forest Service 2010 RPA Assessment*. Ashville: Southern Research Station. Retrieved from www.srs.fs.usda.gov.

Bradbury, J., Cullen, P., Dixon, G., & Pemberton, M. (1995). Monitoring and management of streambank erosion and natural revegetation on the lower Gordon River, Tasmanian wilderness world heritage area, Australia. *Environmental Management, 19*(2), 259.

Breen, B., Curtis, J. A., & Hynes, S. (2017). *Recreational Use of Public Waterways and the Impact of Water Quality (No. 552)*. ESRI working paper.

Cordell, K. (2012). *Outdoor Recreation Trends and Futures: A Technical Document Supporting the Forest Service 2010 RPA Assessment*. Ashville: Southern Research Station. Retrieved from www.srs.fs.usda.gov.

De Ventura, L., Weissert, N., Tobias, R., Kopp, K., & Jokela, J. (2016). Overland transport of recreational boats as a spreading vector of zebra mussel *Dreissena polymorpha*. *Biological Invasions, 18*(5), 1451–1466.

DeFlorio-Barker, S., Wade, T. J., Jones, R. M., Friedman, L. S., Wing, C., & Dorevitch, S. (2017). Estimated costs of sporadic gastrointestinal illness associated with surface water recreation: A combined analysis of data from NEEAR and CHEERS studies. *Environmental Health Perspectives, 125*(2), 215.

Dorevitch, S., Panthi, S., Huang, Y., Li, H., Michalek, A. M., Pratap, P., et al. (2011). Water ingestion during water recreation. *Water Research, 45*(5), 2020–2028.

Eiswerth, M. E., Donaldson, S. G., & Johnson, W. S. (2000). Potential environmental impacts and economic damages of Eurasian watermilfoil (*Myriophyllum spicatum*) in western Nevada and northeastern California. *Weed Technology, 14*(3), 511–518.

Eklund, B., & Watermann, B. (2018). Persistence of TBT and copper in excess on leisure boat hulls around the Baltic Sea. *Environmental Science and Pollution Research*, *25*(15), 14595–14605.

English, J. N., McDermott, G. N., & Henderson, D. (1963). Pollution effects of outboard motor exhaust—Laboratory studies. *Journal of the Water Pollution Control Federation, 35*(7), 923.

Erbe, C. (2013). Underwater noise of small personal watercraft (jet skis). *The Journal of the Acoustical Society of America, 133*(4), EL326–EL330.

Faccioli, M., Font, A. R., & Figuerola, C. M. T. (2015). Valuing the recreational benefits of wetland adaptation to climate change: A trade-off between species' abundance and diversity. *Environmental Management, 55*(3), 550–563.

Fewtrell, L., Jones, F., Kay, D., Wyer, M. D., Godfree, A. F., & Salmon, B. L. (1992). Health effects of white-water canoeing. *The Lancet, 339*(8809), 1587–1589.

Gabel, F., Lorenz, S., & Stoll, S. (2017). Effects of ship-induced waves on aquatic ecosystems. *Science of the Total Environment, 601*, 926–939.

Garrad, P. N., & Hey, R. D. (1987). Boat traffic, sediment resuspension and turbidity in a Broadland river. *Journal of Hydrology, 95*(3–4), 289–297.

Hammitt, W. E., Cole, D. N., & Monz, C. A. (2015). *Wildland Recreation: Ecology and Management*. John Wiley & Sons.

Haslam, S. M. (1978). *River Plants*. London.

Hill, M. P., & Coetzee, J. (2017). The biological control of aquatic weeds in South Africa: Current status and future challenges. *Bothalia-African Biodiversity & Conservation, 47*(2), 1–12.

Hockin, D., Ounsted, M., Gorman, M., Hill, D., Keller, V., & Barker, M. A. (1992). Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. *Journal of Environmental Management, 36*(4), 253–286.

Hussner, A., Stiers, I., Verhofstad, M. J. J. M., Bakker, E. S., Grutters, B. M. C., Haury, J., et al. (2017). Management and control methods of invasive alien freshwater aquatic plants: A review. *Aquatic Botany, 136*, 112–137.

Kempinger, J. J., Otis, K. J., & Ball, J. R. (1998). Fish kills in the Fox River, Wisconsin, attributed to carbon monoxide from marine engines. *Transactions of the American Fisheries Society, 127*, 669–672.

Khan, R. A. (2003). Health of flatfish from localities in Placentia Bay, Newfoundland, contaminated with petroleum and PCBs. *Archives of Environmental Contamination and Toxicology, 44*(4), 485–492.

King, J. G., & Mace Jr., A. C. (1974). Effects of recreation on water quality. *Journal (Water Pollution Control Federation)*, 2453–2459.

La Jeunesse, I., Cirelli, C., Aubin, D., Larrue, C., Sellami, H., Afifi, S., et al. (2016). Is climate change a threat for water uses in the Mediterranean region? Results from a survey at local scale. *Science of the Total Environment, 543*, 981–996.

Liddle, M. J., & Scorgie, H. R. A. (1980). The effects of recreation on freshwater plants and animals: A review. *Biological Conservation, 17*(3), 183–206.

Lüdermann, D. (1968). Water pollution by outboard motors and its effects on fauna and flora. *Helgoländer Wiss. Meeresun, 17*(1–4), 356–369.

Mattos, J. J., Siebert, M. N., Luchmann, K. H., Granucci, N., Dorrington, T., Stoco, P. H., et al. (2010). Differential gene expression in *Poecilia vivipara* exposed to diesel oil water accommodated fraction. *Marine Environmental Research, 69*(Suppl. 1), S31–S33.

Merriam, L. C., & Smith, C. K. (1974). Visitor impact on newly developed campsites in the boundary waters canoe area. *Journal of Forestry, 72*(10), 627–630.

Monz, C., & Leung, Y. F. (2006). Meaningful measures: Developing indicators of visitor impact in the national park service inventory and monitoring program. In *The George Wright Forum* (Vol. 23, No. 2, pp. 17–27). George Wright Society.

Mosisch, T. D., & Arthington, A. H. (1998). The impacts of power boating and water skiing on lakes and reservoirs. *Lakes & Reservoirs: Research & Management, 3*(1), 1–17.

Mujal-Colilles, A., Gironella, X., Sanchez-Arcilla, A., Puig Polo, C., & Garcia-Leon, M. (2017). Erosion caused by propeller jets in a low energy harbour basin. *Journal of Hydraulic Research, 55*(1), 121–128.

Murphy, K. J., & Eaton, J. W. (1983). Effects of pleasure-boat traffic on macrophyte growth in canals. *Journal of Applied Ecology, 20*, 713–729.

O' Sullivan, P. (1990). *The Effect of Recreational Usage, in Particular Canoeing, and Agricultural Input upon the Gorges of the Afon Conwy, North Wales*. Unpublished undergraduate dissertation, Liverpool John Moores University.

Phillip, D. A. T., Antoine, P., Cooper, V., Francis, L., Mangal, E., Seepersad, N., et al. (2009). Impact of recreation on recreational water quality of a small tropical stream. *Journal of Environmental Monitoring, 11*(6), 1192–1198.

Purser, J., & Radford, A. N. (2011). Acoustic noise induces attention shifts and reduces foraging performance in three-spined sticklebacks (*Gasterosteus aculeatus*). *PLoS One, 6*, e17478.

Ruprecht, J. E., Glamore, W. C., Coghlan, I. R., & Flocard, F. (2015). Wakesurfing: Some wakes are more equal than others. In *Australasian Coasts & Ports Conference 2015: 22nd Australasian Coastal and Ocean Engineering Conference and the 15th Australasian Port and Harbour Conference* (p. 779). Engineers Australia and IPENZ.

Sharp, R. L., Cleckner, L. B., & DePillo, S. (2017). The impact of on-site educational outreach on recreational users' perceptions of aquatic invasive species and their management. *Environmental Education Research, 23*(8), 1200–1210.

Slabbekoorn, H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C., & Popper, A. N. (2010). A noisy spring: The impact of globally rising underwater sound levels on fish. *Trends in Ecological Evolution, 25*, 419–427.

Spencer, M. (1995). *Environmental Impact by Canoeing on the Afon Llugwy and Afon Tryweryn*. Unpublished undergraduate dissertation, Liverpool John Moores University.

Steven, R., Pickering, C., & Castley, J. G. (2011). A review of the impacts of nature based recreation on birds. *Journal of Environmental Management, 92*(10), 2287–2294.

Superville, P. J., Prygiel, E., Magnier, A., Lesven, L., Gao, Y., Baeyens, W., et al. (2014). Daily variations of Zn and Pb concentrations in the Deûle River in relation to the resuspension of heavily polluted sediments. *Science of the Total Environment, 470–471*, 600–607.

The Outdoor Foundation. (2017). *Outdoor Participation Topline Report 2017*. Washington, DC: The Outdoor Foundation. Retrieved from www.outdoorfoundation.org.

Tivy, J. (1980). *The Effect of Recreation on Freshwater Lochs and Reservoirs in Scotland*. Perth: Countryside Commission for Scotland.

Walsh, J. R., Carpenter, S. R., & Vander Zanden, M. J. (2016). Invasive species triggers a massive loss of ecosystem services through a trophic cascade. *Proceedings of the National Academy of Sciences, 113*(15), 4081–4085.

Wang, X. J., Zhang, J. Y., Shahid, S., Guan, E. H., Wu, Y. X., Gao, J., et al. (2016). Adaptation to climate change impacts on water demand. *Mitigation and Adaptation Strategies for Global Change, 21*(1), 81–99.

Whitfield, A. K., & Becker, A. (2014). Impacts of recreational motorboats on fishes: A review. *Marine Pollution Bulletin, 83*(1), 24–31.

Zani, J. (2000). *The Effect of Recreational Canoeing on the Riparian Vegetation of the River Dee*. Unpublished undergraduate dissertation, Liverpool John Moores University.