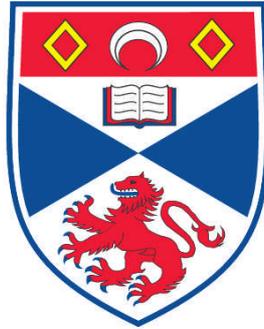


**ECOLOGY AND CONSERVATION OF BOTTLENOSE DOLPHINS
(TURSIOPS TRUNCATUS) IN THE NORTH-EASTERN ADRIATIC
SEA**

Caterina Maria Fortuna

**A Thesis Submitted for the Degree of PhD
at the
University of St. Andrews**



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ECOLOGY AND CONSERVATION
OF BOTTLENOSE DOLPHINS (TURSIOPS TRUNCATUS)
IN THE NORTH-EASTERN ADRIATIC SEA

CATERINA MARIA FORTUNA

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of
Philosophy
University of St. Andrews

December 2006



To my family.

To Lucia and Paolo, my guardian Angels.

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This work started in 1995 and has encompassed fundamental years of my life. Honestly, it would be difficult not to forget someone that helped, in some way or another, in this long and complex delivery. Many people crossed my life and helped substantially, sometimes with a providential smile or other times with many years of working and walking together. I would feel very bad finding out a minute after having bounded this thesis that I have mentioned most but forgotten someone...

So I decided to 'forget' all names, acknowledging people in a different way. I really hope this 'different way' will work and you will all recognise your precious contribution in the following lines...

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...thanks again to all... for all...

DECLARATIONS

I, Caterina Maria Fortuna, hereby certify that this thesis, which is approximately 48,000 words in length, has been written by me, that it is the record of work carried out by me and that it has not been submitted in any previous application for a higher degree.

date 18/12/2006 signature of candidate

I was admitted as a research student in January 2001 and as a candidate for the degree of Ph.D. in January 2002; the higher study for which this is a record was carried out in the University of St Andrews between 2001 and 2006.

date 18/12/2006 signature of candidate

I hereby certify that the candidate has fulfilled the conditions of the Resolution and Regulations appropriate for the degree of Ph.D. in the University of St Andrews and that the candidate is qualified to submit this thesis in application for that degree.

date 18/12/2006 signature of supervisor

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ABSTRACT

Bottlenose dolphins of the Kvarnerić (NE Adriatic Sea) live in an area of increasing human impact, through tourism and small-scale fisheries. This thesis aimed to assess the status of the local population and to inform managers on factors affecting their distribution and abundance, using data from 1995-2003. Habitat modelling indicated a significant negative impact of proximity to the main 'marine highway' and to marine petrol stations. Evidence was found that dolphins may recently have reached a tolerance limit to the number of boats using the area and that they remember crowded areas from one year to the next. Dolphin presence was positively related to particular depths and trawling areas. Apparent adult survival rate was estimated to be significantly lower than for any other bottlenose dolphin population and first year calf survival was also low. A decreasing trend in fecundity rate was found. The population showed a considerable rate of non-random temporary emigration from the study area. The estimated size of the population was small and similar to two other European bottlenose dolphin populations (Moray Firth in Scotland and Shannon Estuary in Ireland). A significant decrease in abundance of about 39% from 1995 was estimated. PVA confirmed the importance of female adult survival to population viability and indicated that the current rate of human-induced mortality is unsustainable. Local extinction risk within three generations was estimated to be high (35%). Applying the IUCN Red List Criteria, the Kvarnerić population should be listed as *Endangered* under Criterion C and E. This study gives an important insight into the ecology of Adriatic bottlenose dolphins and indicates the need for a regionally and locally synergistic approach to conserve this population.

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CHAPTER 1: GENERAL INTRODUCTION

1.1 CONSERVATION OF BOTTLENOSE DOLPHINS IN A EUROPEAN AND MEDITERRANEAN CONTEXT

1.1.1 Conservation and conservation biology

The word “conservation” can be used in an extremely controversial way. Some understand it as “sustainable use”, others as “integral protection” (see for example the discussion entertained on this point at the International Whaling Commission; Annual Reports of the IWC 2003, 2004, 2005). At a high political level, it is sometimes considered less seriously and even perceived as opposition to progress. Holt and Talbot (1978) define conservation as the means to maintain the resource system in a “desirable state[s]”. It is obviously necessary to define such states and being aware that definitions can change according to different historical periods and cultural perceptions (Holt and Talbot 1978). The conservation of nature can be defined as “*protection, improvement, and the use of natural resources according to principles that will assure their highest economic or social benefits for man and his environment now and into the future*” (Choudhury and Jensen 1999). Since a species cannot be disjointed from its environment, conservation should aim to avoid the destruction of any single component of an ecosystem to maintain its balance. In fact, the extinction of a species or the destruction of its habitat, which will inevitably lead to its extinction, is an irreversible act which represents a loss of unknown value (Turner *et al.* 2003, Baumgärtner *et al.* 2006, Hanski 2005).

While the net value of any one habitat and species is practically impossible to represent in monetary figures, economic reasons for conservation can be demonstrated (Costanza *et al.* 1997). In the domain of the marine environment, tourism (traditional, nautical and eco-tourism, bird- and whale-watching, scuba diving, etc.), fisheries, education and

science can all benefit from a safe and harmonious management of the marine ecosystem. As Leopold (1949) states “conservation is a state of harmony between men and land”.

Conservation biology is, in simple terms, the scientific study of all phenomena that affect the maintenance, loss, and restoration of biological diversity (Caughley and Gunn 1996). Philosophically, the concern of this branch of biology is to help save the diversity of life on Earth, through applied research. In the realm of research, biologists seek creative and effective ways to address a wide diversity of ecological problems, ranging from endangered species to regional conservation planning, with an aim to translate this into developing better conservation tools, analyses and techniques.

One of the main aims of conservation biology is to understand the ecological mechanisms that make some species more prone to population decline, range contraction, and extinction than others (Caughley 1994; Pimm *et al.* 1988). Such understanding theoretically allows biologists to predict the vulnerability of species before they decline, thereby allowing the application of management techniques to improve their chances of survival (Caughley 1994).

There are many reasons why some species may be more prone to extinction than others. These include: small population size, small geographical range, specialized habitat requirements, large body size, and ‘slow’ life histories (Beissinger and McCullough 2002, Morris and Doak 2002).

Several hypotheses have been presented as ‘the best approach to conservation’ by conservation biologists. Although ‘single species’ conservation has been subjected to critical examination, especially by those endorsing the ‘ecosystem approach’ (Grumbine, 1994), Zacharias and Roff (2001:72) suggest, that *‘the cryptic and fluid*

nature of marine environments lends greater support for the use of indicator species’.

In particular, they propose that the ‘*flagship*’ concept may be better suited to marine environments than other concepts due to the association of species with distinctive critical habitats such as feeding and breeding grounds. The existence of critical habitats is also applicable to several cetacean species. Zacharias and Roff (2001:60) also recognised that ‘*similar to the umbrella concept, the ultimate goal of advocating flagships is the protection of their habitats and constituent species*’. Hence the possibility of conserving a ‘flagship’ and charismatic species, such as the bottlenose dolphin, could ensure, as a logical result, the protection of the entire ecosystem. In a very broad sense, it could be expected that, while coping with the mitigation of all of the potential causes of decline of, for example, a bottlenose dolphin population in a defined area, there is the potential of consequently protecting other interrelated terrestrial ecosystems. In some aspects, particularly marine litter, species conservation measures may encroach into the terrestrial realm, despite the fact that the species themselves never physically contact the shore. Therefore, by effectively protecting a single species at the top of the food web, we could find ourselves committed to an integrated coastal zone management system.

Marine Parks are established to protect and maintain endangered marine ecosystems and the biological diversity they support. Economic use and protection must be made compatible, as these areas are invariably economically important for the features they protect. As Butler (1991) points out “the environment is tourism's resource”. Tourism is a business and a product is being sold. The product is an experience, which in many cases is inherently linked to the environment. Any reduction in environmental quality may result in a reduction in the willingness of users to pay (Butler 1991). There are many factors that affect the marine environment as a whole and by association its

economics. Industrial and urban runoff, eutrophication from sewage and agricultural inputs, physical impacts from maritime activities including destructive fishing practices and, in a more concentrated area, degradation from excessive or mismanaged tourism use all have an effect (for example, Meltzer 1998, Boersma and Parrish 1999, Sumaila *et al.* 1999, Hyrenbach *et al.* 2000).

1.1.2 Geographical and cultural context

The Mediterranean Sea (Fig. 1.1) is a semi-enclosed basin containing many of the characteristics of the open ocean, e.g. deep and intermediate water formation, jets, eddies, and intense air-sea interaction (Baum 2004). This oceanographically complex area is characterised by two main regions - the eastern and the western basins - which are subdivided into several sub-regional seas. The eastern Mediterranean basin (totalling over 2.5 million km²) includes the Azov, Black, Marmara, Aegean, Levantine, Cretan, Ionian and Adriatic Seas. The eastern Mediterranean connects to the western Mediterranean basin through the Strait of Sicily (or Sicily Channel) and the Strait of Messina.

The context in which nature conservation policy shapes itself is very important, and the Mediterranean is no exception. In terms of culture and socio-economics this region is subject to widely different regimes, with the European Union and Associate countries on one side and several autonomous countries on the other. The distribution of natural resources and wealth is extremely polarised and often there is no clear direct relationship between available resources in a country and its Gross Domestic Product. Language is also a serious issue. Besides this, even within the European countries themselves, large differences exist resulting from cultural and historical heritage. This scenario makes negotiation difficult especially when it comes to the perception of the environment, its conservation and use.

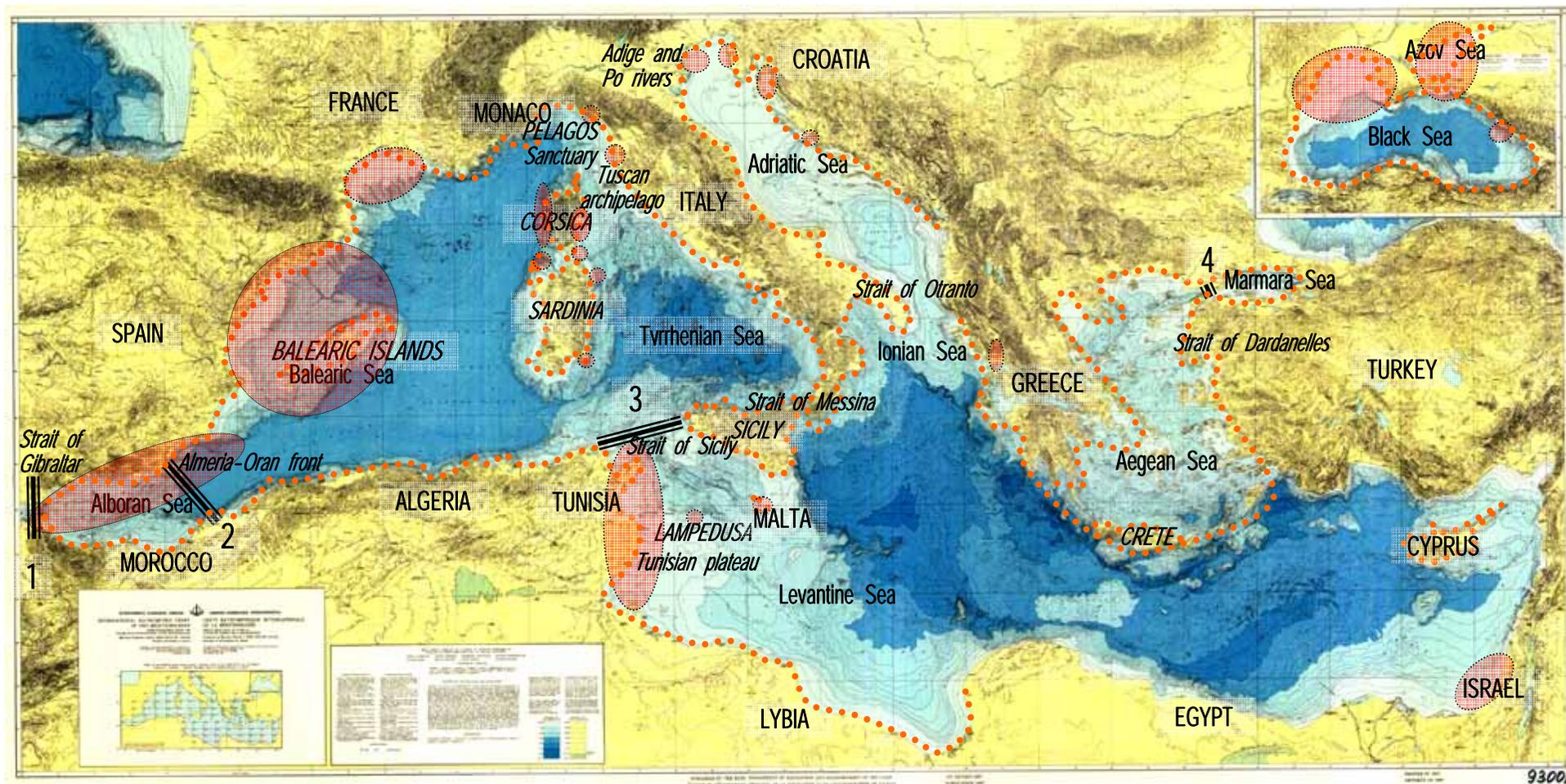


Figure 1.1 - Map of the Mediterranean Sea, showing known study areas for bottlenose dolphins (pale oval polygons), four ecological boundaries (indicated from the left to the right of the map by triple black lines and numbered 1, 2, 3, 4) as proposed by Natoli *et al.* (2005), and approximate coverage of data on strandings and occasional sightings (dotted orange line)

“Common” and “National” interests seem to always clash in the name of “all benefits now (before the end of a policy maker term)” (Bräutigam 2001). In European countries such terms last between 3 and 5 years, depending on the system.

The Mediterranean, as a Common Pool Resource (CPR) for the bordering nations, is like many other CPRs caught in an inevitable process leading to its destruction (see for example, Hardin 1968, Ostrom *et al.* 1999, Jensen 2000), often exacerbated by strong cultural differences (Bardhan and Dayton-Johnson, 2002). CPR theory emphasizing the importance of contextual physical, political, economic, legal and scientific factors (Edwards and Steins 1999, Steins and Edwards 1999, Van Ginkel 1999, Agrawal 2001) could be beneficial in developing new synergistic strategies and overcoming some management obstacles in this region. Developing international negotiation techniques based on cooperation appears to be the only possible road towards reversing environmental degradation, especially within the Mediterranean Sea. This theoretical approach has been adopted by a number of international agreements applicable in the region. Several international treaties and management bodies relevant to scientific exploration, protection and exploitation of the marine mammals and their ecosystem in the Mediterranean Sea already exist, such as CIESM (1919), IARW-IWC (1946), GFCM (1949), CFCLRHS (1958), CITES (1963), Ramsar (1971), MARPOL (1973-1978), the UNEP Regional Seas Programme (1974), Barcelona Convention (1976), Bern Convention (1979), Bonn Convention or CMS (1979), UNCLOS (1982), Agenda 21 (1989), CBD (1992), EU Habitats Directive (1992), SPA Protocol (1995), ACCOBAMS (1996), PELAGOS Sanctuary (1999), ICCAT (1969)¹.

¹In acronym alphabetic order: Agreement on Conservation of Cetaceans in the Black Sea, Mediterranean Sea and adjacent North Atlantic area (ACCOBAMS), Convention for the Protection of the Mediterranean against Pollution (Barcelona Convention), Convention on the Conservation of European Wildlife and Natural (Bern Convention), Convention on Biological Diversity (CBD), Convention on Fishing and Conservation of Living Resources of the High Seas (CFCLRHS), International Commission for the Scientific Exploration of the Mediterranean Sea (CIESM), Convention on International Trade in

Strangely, rather than working synergistically towards a common goal - the protection and sustainable use of the ecosystem, ultimately conserving all species, including top predators - many of these agreements simply overlap. This could be related to the fact that usually National focal points for different treaties and commissions are different people based in different Ministries, underlining the intrinsic lack of coordination at the national level (Dietz *et al.* 2003). This, in addition to inherent ministerial bureaucracy, translates into a lack of National follow-up of international negotiation and achievements (Edwards and Hulme 1994, Dietz *et al.* 2003). In contrast, even when some coordination is put into place, all these bodies move too slowly and ineffectively to really ensure conservation. This will become clear throughout this thesis where the case of the Adriatic bottlenose dolphin is concerned.

In this context, the work of NGOs becomes disproportionately important, causing in some cases serious additional problems or pretexts to the work of Governments (Haley and Clayton 2003). This is particularly so when NGOs, as entities representing civil society and with a specific role in influencing policy makers, substitute the duties of Government by drawing up new policies and even managing the commons (for example, as in the case of some Italian MPAs). Such an approach is obviously helpful in the short-term because it gives an immediate answer to a problem made possible by the flexibility of NGOs (Fyvie and Ager 1999), but it is detrimental in the long-term for two main reasons: a) given the limited economic and human resources, Governments take

Endangered Species of Wild Fauna and Flora (CITES), Convention on Migratory Species (CMS), Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (EU Habitat Directive), General Fisheries Commission for the Mediterranean Sea (GFCM), International Agreement for the Regulation of Whaling-International Whaling Commission (IARW-IWC), International Convention for the Conservation of Atlantic Tunas (ICCAT), Protocol of 1978 Relating to the International Convention for the Prevention of Pollution From Ships, 1973 (MARPOL 73/78), International Sanctuary of Marine Mammals (PELAGOS Sanctuary), Convention on Wetlands (Ramsar), Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA), United Nations Convention on the Law of the Sea (UNCLOS), United Nations Environmental Program (UNEP).

the chance to “de-prioritise” issues which are dealt by NGOs; and b) NGOs managing the commons enter the paradox of being the “inspector” and the “inspected”.

1.1.3 The Adriatic Sea

The Adriatic Sea is the most northerly arm of the Mediterranean Sea. It is bordered on the western side by Italy and on the eastern side by the south-eastern European peninsula (including the Balkan countries and Greece). This elongated semi-enclosed sea is connected to the rest of the Mediterranean Sea by the 70 km wide Otranto Strait. Renewal of water in the Adriatic is estimated to be in the range of 3-10 years (Zore-Armanda 1969), compared to the 70-100 years for the Mediterranean as a whole (Lacombe and Richet 1982). The general Adriatic circulation is characterised by an inflow on the eastern side of the Otranto Strait and a southerly current along the western seaboard (Poulain 1999, 2001).

The intensity of this circulation is promoted by the seasonal pattern of air-sea interactions (Brana and Krajcar 1995, Artegiani *et al.* 1997b). In winter, the currents are cyclonic in nature and the water column is cooled by the strong katabatic North-east wind, locally known as Bura. This wind helps vertical mixing in the water column and causes its homogeneity (Brana and Krajcar 1995). The other dominant wind found in the Adriatic is from the South-east, locally called Jugo, characterised by warm humid air from the Mediterranean. Both winds - Bora and Jugo - represent transient phenomena, which can last several days. The summer circulation is characterised by migrating cyclones: as a cyclone approaches the Adriatic, Jugo will blow, and as it leaves, Bora recurs (Orlić *et al.*, 1994). However, currents are weaker and this period is characterised by vertical stratification and horizontal heterogeneity of the water column due to intensive heating and input of freshwater causing spatial and temporal complexity of the general circulation (Orlich *et al.* 1992, Brana and Krajcar 1995). Bora

and Jugo also have an effect on the sea levels in the Adriatic. Bora induces a complex response with sea levels varying; the current field is dominated by the wind-curl effect. Jugo pushes water into the northern Adriatic generating, due to the combined effects of the wind curl and bottom slope, a cyclonic gyre in the north-eastern Adriatic and an anti-cyclonic gyre near the western coast (Orlić *et al.* 1994).

Geographical position, bathymetry and climatic characteristics make the Adriatic Sea one of the few places in the world where dense water is formed (Nielsen 1912 and Schott 1915 cited by Vilibic and Orlic 2002). Dense water is generated in the northern Adriatic where the shallow basin, less than 100 m, is exposed to the cold winter wind from the North-east, this is further enhanced by the significant cold river runoffs (Zore-Armanda 1963, Hendershott and Rizzoli 1976, Orlić *et al.* 1992). This process of dense water formation is important because it allows the exchange of physical and biochemical properties between the surface and deep layers (Lascaratos *et al.* 1999).

The basin is partitioned in three sub-regions, based mainly on the bathymetry: the northern, middle and the southern Adriatic (Artegiani *et al.* 1997a). This is complicated by substantial oceanographic differences between the western and eastern side, particularly water column characteristics, currents, productivity, degree of local pollution and biodiversity. In terms of biogeochemical characteristics, there is a general trend of nutrient concentrations decreasing from North to South, due to riverine nutrient input, particularly in the north-western Adriatic. On the whole, phosphorus is the limiting nutrient in the basin; however nitrogen depletion may also be a factor in the middle and particularly the southern Adriatic surface water (Zavatarelli *et al.* 1998). In the Spring-Summer strong bacterial regeneration of organic matter can lead to oxygen depletion and nutrient increase at depth (Zavatarelli *et al.* 1998). Some areas of the Adriatic Sea, particularly the north-western coast, are periodically affected by mucilage

events. Different hypotheses have been suggested, however it seems to be particularly linked to high river flows, high water temperature and pollution events.

The northern Adriatic lies on the continental shelf. Its western side is characterised by sandy coasts gently sloping down to 30-40 meters. The water column appears mainly eutrophic, especially close to the Italian coasts, with salinity relatively low and some areas showing a high degree of pollution, due to the influence of the Adige and Po river deltas (Degobbis *et al.* 1986, Caricchia *et al.* 1993, Tankere and Statham 1996). The Po is the dominant influence not only in this area but the whole Adriatic (Supić and Orlić 1999). In contrast, the eastern side is punctuated by channels, islands and islets, submerged reefs and characterised by rocky shores that abruptly drop to depths of up to 100 meters. The water column is oligotrophic and pollution is very localised and relatively low (Degobbis *et al.* 1986, Limić and Valković 1996, Tankere and Statham 1996, Kljaković-Gašpić *et al.* 2002).

The shallow northern Adriatic is believed to be one of the most threatened ecosystems in the world due to severe pollution and overexploitation of its natural resources (de Walle *et al.* 1993). The degradation of any ecosystem is often first indicated by reductions in biological diversity. The disappearance of the once “common” common dolphin may be related, at least to a certain extent, to the well known environmental abuse of this region and to the past culling policy adopted by Italy and ex-Yugoslavia (Holcer 1994, Bearzi *et al.* 2004).

1.1.4 The Mediterranean bottlenose dolphins

1.1.4.1 Distribution and abundance

Available records suggest that the bottlenose dolphin is probably the most widely-distributed species in the Northeastern Atlantic and Mediterranean (Notarbartolo and

Demma 1997). Notarbatolo *et al.* 1993 reported that bottlenose dolphin groups were most abundant in regions where neritic waters were predominant (e.g. the Sicily Strait and the northern Adriatic Sea) or important (e.g. along the wide shelf of Sardinia's west coast and the waters surrounding the Tuscan Archipelago in the northern Tyrrhenian Sea). It should be noted, however, that within the Mediterranean, bottlenose dolphins are found in a wide variety of habitats, ranging from lagoons and river deltas to the open sea, see Figure 1.1 (Forcada *et al.*, 2004, Bearzi *et al.*, 2004, Bearzi *et al.*, 2005, Cañadas and Hammond, 2006).

Bottlenose dolphins have been anecdotally reported almost everywhere in the western Mediterranean basin (Fig. 1.1), although reliable quantitative information from systematic research studies is more limited (Table 1.1). The near absence of cetacean research in most of the eastern basin (including the Ionian and Levantine Seas) means there is little information on presence, distribution and abundance of bottlenose dolphins. Exceptions within that region are represented by projects carried out in Israeli waters, Tunisian plateau (including Lampedusa Island) and a limited part of the Greek Ionian Sea (Pulcini *et al.* 2004, Bearzi *et al.* 2005, Bearzi *et al.* 2006, Scheinin *et al.* 2005). It is clear that a lack of information (e.g. see summary in Cañadas *et al.* 2004) currently prevents any definitive statements on the status of the Mediterranean bottlenose dolphin.

1.1.4.2 Definition of the term “population” in the Mediterranean context

Of course, any statement about the status of Mediterranean bottlenose dolphins (and indeed whether it is sensible to make such a statement for such a broad geographical area) depends on the criteria and reference points chosen, including ultimately the ‘unit-to- conserve’ (e.g. see IWC, 2006) and the definition of a ‘population’ (Wells and Richmond 1995; Waples 1998, 2002). Detailed discussion of this important topic in

conservation biology is outside the scope of this thesis. However, in the context of bottlenose dolphins in the Mediterranean, the meta-population concept may be useful. This concept defines a 'meta-population' as comprising 'local populations' that are discrete or relatively discrete entities in space, which interact via migration and gene flow (Hanski and Gaggiotti 2004). The concept of meta-population also implies that the processes of 'geographical extinction' and 'recolonisation' occur regularly. In ecology, it is widely accepted that fragmentation of the landscape represents the most visible anthropogenic threat to the survival of natural populations (e.g. Hanski 2005). Such fragmentation can occur within the range of a local population, particularly for highly mobile species. In extreme cases, this might ultimately lead to both genetic and geographical isolation (Freedman *et al.* 2003, Gaggiotti *et al.* 2004).

Natoli *et al.* (2005) propose a possible structure for a Mediterranean meta-population based on genetic studies. They examined mitochondrial-DNA for 90 genetic samples from a variety of locations and found a 'macro' structure over the geographical range from Gibraltar to the Black Sea for contiguous 'local' populations. They suggest at least four possible 'ecological boundaries': the Gibraltar strait, the Almeria-Oran front, Sicily and Dardanelles straits (labelled 1 – 4, respectively, in Fig. 1.1). These reflect the habitat dependence of local populations, as a result of the way in which different habitats, characterised by particular hydrographical features, influence patterns of movement of their prey and themselves. As in other parts of the world, bottlenose dolphins in the Mediterranean appear to have highly adaptive feeding habits (Stewart 2004) with a preference for demersal prey (Blanco *et al.* 2001). Bottlenose dolphins in the Alboran Sea appeared to prefer waters between 200 and 600m depth and a steep sea bottom, especially around the 'Seco de los Olivos', an area that is also heavily used by trawlers (Cañadas and Hammond 2006). An overlap with bottom trawler fishing

grounds was found in the north-eastern Adriatic Sea in a different environmental context (see Chapter 3).

Despite sample size limitations in the Natoli *et al.* (2005) study, it seems sensible to address conservation issues of bottlenose dolphins in the Mediterranean at the ‘regional’ if not the ‘local’ population level, rather than focussing on the entire basin, although some threats may act at this level. Fortunately, considerable new information has recently been published for both the eastern and western Mediterranean (e.g. Ben Naceur *et al.* 2004, Forcada *et al.* 2004, Bearzi *et al.* 2005, Cañadas and Hammond 2006). Long-term studies are now able to produce quantitative information on trends in abundance and survivorship (this study). These new data already allow, at least in some areas, threats and conservation needs to be identified and possible management schemes developed in a pragmatic manner. It is neither necessary nor wise to wait for information for the whole basin before acting in these areas.

Despite the lack of survey effort in many areas (Fig. 1.1), ‘local populations’ or components of them have been reported for coastal waters (Bearzi *et al.* 1997, Vella 1999, Fortuna *et al.* 2000, Mackelworth *et al.* 2002a, Impetuoso *et al.* 2003, Ben Naceur *et al.* 2004, Forcada *et al.* 2004, Frantzis *et al.* 2003, IWC 2004, Pulcini *et al.* 2004, Ripoll *et al.* 2004, Bearzi *et al.* 2005, Genov and Fortuna 2005, Scheinin *et al.* 2005, Cañadas and Hammond 2006). It is certainly feasible that there may be more in the south-eastern basin.

Although it has been shown that at least the two local populations in the Alboran and Balearic Seas showed the existence of both inshore and off-shore groups (Forcada *et al.* 2004; Cañadas and Hammond 2006), thus far the Mediterranean bottlenose dolphins have been described as mostly scattered into relatively small inshore ‘local populations’ (e.g. Notarbartolo di Sciara and Demma 1994), where ‘local populations’ very likely

represent only part of what is usually intended by these two words (see above, under the definition of ‘meta-population’). This definition could also be largely affected by a perception bias related to existing studies that are mainly coastal, characterised by small study areas (100-2,000 km²) and small research platforms (rigid hull inflatable boats). Wider surveys (4,000-80,000 km²) on bottlenose dolphins have revealed the existence of offshore animals (Ben Naceur *et al.* 2004; Forcada *et al.* 2004; Cañadas and Hammond 2006).

1.1.4.3 Mediterranean bottlenose dolphin group size

Mean group size appears to vary according to location, from typically small (groups of 3-7 animals) numbers in coastal areas (Bearzi *et al.* 1997; Ben Naceur *et al.* 2004) to large (typically up to 35 and as high as 180) numbers offshore (Forcada *et al.* 2004; Cañadas and Hammond 2006). However, as the definition of ‘group’ varies across studies, especially for large groups, this information should be taken as indicative only. Mixed-species groups are uncommon, but not rare (for example with pilot whales, A. Cañadas 2006 *pers. comm.*).

While the Mediterranean bottlenose dolphin is considered ‘common’ in terms of distribution, the same may be not true for abundance. There are no published basin-wide abundance estimates of the bottlenose dolphin populations of the Mediterranean Sea. A worldwide review of interactions between cetaceans and gillnets (IWC 1994) recognised the limited data available but referred to a personal communication from Notarbartolo di Sciara (IWC 1994, p.29) in which a crude estimate of at least 10,000 bottlenose dolphins was suggested based on limited survey data and an unspecified extrapolation to the whole area. In recent years, local absolute and relative abundance and density estimates, based on mark-recapture or distance sampling, have become available for a few areas of the Mediterranean basin including the Black Sea (Table

1.1). Rough estimates based on the number of photo-identified dolphins also exist for a few other areas (Table 1.1). Available data on population abundance estimated from mark-recapture methods collected in other parts of Europe is given in Table 1.2.

On the basis of present knowledge on the distribution of bottlenose dolphins, and on the oceanographic and geographic characteristics of the Mediterranean, key areas of distribution and abundance could include: the Alboran Sea; the Balearic Sea and Islands; the south-western coastal area of the International PELAGOS Sanctuary (Ligurian and Tyrrhenian Sea); the Adriatic Sea; the Tunisian Plateau including Lampedusa island; waters surrounding the middle East countries (including Cyprus and Israel); the Aegean Sea; the Turkish straits system (Dardanelle strait and Marmara Sea); and the Black Sea.

Concerning abundance, rigorous extrapolations are not possible because most of the identified areas may reflect the number and distribution of research projects rather than the real presence and abundance of dolphins. Although one might expect research projects to occur in areas where the relative density of animals is particularly high, it must be remembered that they are often driven by other needs (e.g. logistics and economic feasibility) as was the case for the present study.

Table 1.1 - Summary of information on abundance of bottlenose dolphins in the Mediterranean basin (including the Black Sea)

Geographic Area	Study area (km ²)	Sampled area	Years	N	CV	95% CI	Estimation method	Source
<i>Western Mediterranean area</i>								
Alboran sea (Spain)	11,821	In- and off-shore	2000-3	584	0.28	278 – 744	Distance sampling and GAMs	Cañadas & Hammond 2006
Almeria (Spain)	4,232	In- and off-shore	2001-3	279	0.28	146 – 461	Distance sampling and GAMs	Cañadas & Hammond 2006
Balearic Islands and Catalonia (Spain)	86,000	In- and off-shore	2002	7,654	0.47	1,608 - 15,766	Distance sampling	Forcada <i>et al.</i> 2004
Gulf of Vera (Spain)	6,164	In- and off-shore	2003-5	256	0.31	188 – 592	Distance sampling and GAMs	Cañadas unpublished
Valencia (Spain)	32,270	In- and off-shore	2001-3	1,333	0.31	739 - 2,407	Distance sampling	Gomez de Segura <i>et al.</i> 2006
Asinara island National Park (Italy)	480	Inshore	2001	22	0.26	22 – 27	Mark-recapture (closed pop)	Mackelworth <i>et al.</i> 2002a
Corsican waters (France)	~ 5,000	Inshore	2000	153	-	-	Max no of photo-identified in 2000	Dehrmain <i>et al.</i> 2006
<i>Eastern Mediterranean area</i>								
Lampedusa island (Italy)	200	Inshore	1996-00	140	-	-	Discovery curve (asymptotic)	Pulcini <i>et al.</i> 2004
Tunisian waters	~ 750	Inshore	2001 and 03	3,977	0.34	1,982-7,584	Distance sampling	Ben Naceur <i>et al.</i> 2004
Maltese waters	-	In- and off-shore	1997-1998	659	0.34	352-1,375	Distance sampling	Vella 1999
Israeli Mediterranean coast (Israel)	-	Inshore	1999-04	85	-	-	Max no of photo-identified (increasing)	Scheinin <i>et al.</i> 2005
Ionian sea (Greece)	480	Inshore	1993-03	48	-	-	Max no of photo-identified (increasing). Only 12 residents.	Bearzi <i>et al.</i> 2005

Table 1.1 (continued) - Summary of information on abundance of bottlenose dolphins in the Mediterranean basin (including the Black Sea)

Geographic Area	Study area (km²)	Sampled area	Years	N	CV	95% CI	Estimation method	Source
<i>Eastern Mediterranean area</i>								
Central Adriatic sea (Kornati and Murta sea, Croatia)	300	Inshore	2002	14	-	-	Max no of photo-identified (increasing)	Impetuoso <i>et al.</i> 2003
North-eastern Adriatic sea (Kvarnerić, Croatia)	1,000	inshore	1997	113	0.06	107-121	Mark-recapture (closed pop)	Fortuna <i>et al.</i> 2000
=	2,000	inshore	2001-2	128	0.12	106 – 158	Mark-recapture (open pop)	Wiemann <i>et al.</i> 2003
North-eastern Adriatic sea (Kvarnerić, Croatia)	800	Inshore	1990-4	120	-	-	Discovery curve (asymptotic) adjusted for a proportion of unmarked (stable)	Bearzi <i>et al.</i> 1997
North Adriatic sea (Gulf of Trieste, Slovenia)	600	Inshore	2002-4	47	-	-	Max no of photo-identified (increasing)	Genov <i>et al.</i> 2004 Genov & Fortuna 2005
<i>Turkish Strait System</i>								
Turkish Strait	~ 100	inshore	1997	485	-	203–1,197	Distance sampling	Dede (1999), cited after: IWC (2004)
=	~ 100	inshore	1998	468	-	184–1,186	Distance sampling	Dede (1999), cited after: IWC (2004)
<i>Black sea area</i>								
Kerch Strait	890	Inshore	2001	76	-	30 – 192	Distance sampling	Birkun <i>et al.</i> (2002)
=	890	Inshore	2002	88	-	31 – 243	Distance sampling	Birkun <i>et al.</i> (2003)
=	862	Inshore	2003	127	-	67–238	Distance sampling	Birkun <i>et al.</i> (2004a)
NE shelf area of the Black sea	7,960	Inshore	2002	823	-	329 – 2,057	Distance sampling	Birkun <i>et al.</i> (2003)
Northern and NE shelf area of the Black sea	31,780	Inshore	2002	4,193	-	2,527–6,956	Distance sampling (aerial survey)	Birkun <i>et al.</i> (2004a)

Table 1.2 - Summary of available information on abundance of bottlenose dolphins in Europe (Mediterranean area excluded)

Geographic Area	Study area (km²)	Sampled area	Years	N	CV	95% CI	Estimation method	Source
Sado estuary (Portugal)	213	Inshore	1997	30	-	-	Total count	Gaspar 2003
Azores (Portugal)	-	Offshore	1999-04	907	-	-	Max no of photo-identified (increasing).	Silva <i>et al.</i> 2005
Moray Firth, Scotland (UK)	5,230	Inshore	1992	129	0.12	110 – 174	Mark-recapture (closed pop)	Wilson <i>et al.</i> 1999b
=		Inshore		85		76-263	Only well-marked animals	Durban <i>et al.</i> 2005
Sound of Barra, Scotland (UK)	50	Inshore	1995-98	9	-	6-15	Mark-recapture (closed pop)	Grellier & Wilson 2003
Shannon estuary (Ireland)	150	Inshore		113	0.14	94 – 161	Mark-recapture (closed pop)	Ingram 2000

1.1.5 International conservation policy on bottlenose dolphins

Cetaceans are protected internationally under several multilateral agreements and conventions, such as the Barcelona, Bonn and Bern Conventions and ACCOBAMS (see Paragraph 1.1.2). The latter, an offshoot of the Bonn Convention of the UN, is the most relevant international agreement to cetacean conservation in Croatia, in terms of target species and geographic area.

ACCOBAMS has been ratified by 19 countries² out of the 29 possible signatories and entered into force on 1st June 2001. The remaining 10 countries are: Algeria, Bosnia-Herzegovina, European Commission, Egypt, Israel, Russian Federation, Serbia-Montenegro, Slovenia, Turkey, and UK. Concerning the conservation of the bottlenose dolphin, the First Meeting of the Parties held in Monte Carlo in 2002 approved the “*ACCOBAMS International Implementation Priorities for 2002-2006*” (ACCOBAMS 2002), which included the following actions relevant to the bottlenose dolphin:

- Action 8 Development of a “*Conservation plan for common bottlenose dolphins (*Tursiops truncatus*) in the Mediterranean Sea*”, in relation to Article 4 of the Conservation Plan.
- Action 4 “*Development and implementation of pilot conservation and management actions in well-defined key areas containing critical habitat for populations belonging to priority species*”, in relation to Article 3 of the Conservation Plan. Under this Action four areas were identified as promising candidates, one of which was the Kvarnerić area (Lošinj-Cres Archipelago).

Bottlenose dolphins are also listed in CITES Appendix II and their trade is furthermore strictly controlled through the European Community Regulation N 3626/82, which in addition controls the accommodation, care, use, sale, or disposal of specimens after import.

² Albania, Bulgaria, Croatia, Cyprus, France, Georgia, Greece, Italy, Lebanon, Libya, Malta, Monaco, Morocco, Portugal, Romania, Spain, Syria, Tunisia, Ukraine.

Bottlenose dolphins are protected nationally in all European countries of the Mediterranean basin, according to the requirements of the European Commission Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (Council Directive 92/43EEC, 21 May 1992), better known as the “Habitats Directive”. All cetaceans are listed in *Annex IV – Species of Community interest in need of strict protection*. The bottlenose dolphin, together with the harbour porpoise (*Phocoena phocoena*), is specifically listed in *Annex II - Species of Community interest whose conservation requires the designation of Special Areas of Conservation*. Under Article 1(k) of the EU Habitats Directive, a site of Community importance is defined as “*a site that contributes significantly to the maintenance or restoration at a favourable conservation status of a natural habitat type in Annex I or of a species in Annex II*”. In Article 1(l) a Special Area of Conservation (SAC) is defined as “*a site of Community importance where necessary measures are applied to maintain, or restore, to favourable conservation status, the habitats or populations of the species for which the site is designated*”. To become accepted as part of the European NATURA 2000 Network of protected areas, proposed SACs must be shown to be of particular importance for the conservation of the species. Therefore, under the Habitats Directive, a species or a habitat is generically protected, and also a species in its particular habitat is specifically protected, assigning in effect a theoretical double weight to any protection action taken under this framework. As such the Directive could be soon relevant to the Kvarnerić bottlenose dolphin’s population because Croatia became in an Associated Candidate Country in January 2006, officially starting the process of accession to the European Union as a full Member.

1.1.6 Successful examples of protected areas

Due to the geographic and cultural contexts there are not many examples of good practice of cetacean conservation initiatives in Europe, either inside or outside the Mediterranean basin. One positive example is the PELAGOS Cetacean Sanctuary in the Ligurian and north-Tyrrhenian Sea. In November 1999, Italy, France and Monaco met in Rome to sign the agreement for the creation of the PELAGOS Cetacean Sanctuary, a protected area for cetaceans in the Mediterranean Sea, approximately 100,000 km² wide, between the continental coast of Italy, Monaco and France, Corsica, and northern Sardinia. The Agreement entered into force in 2002 after the ratification process was completed by Italy. For the first time in Europe, three Mediterranean countries combined to create, survey and manage an area largely occurring in international waters. This represented a significant step towards the conservation of the Mediterranean Sea ecosystem and the sanctuary has been described as ‘*a watershed in Mediterranean conservation*’ (Scovazzi 2001).

The principal objective of this Cetacean Sanctuary in Article 4 of the PELAGOS Agreement is “*to guarantee a favourable conservation status of sea mammals while protecting, also their habitats and preventing negative direct or indirect impacts of human activities*”. This should be undertaken through managing human activities to ensure viable populations of sea mammals and the protection of their habitats and to sensitise professionals and users of the sea and the public. Included in the accord are the commitments to: oversee the zone with the priority to reduce pollution from terrestrial sources; forbid all deliberate take and disturbance; apply international and European regulation on drift nets and fishing; reduce noise impacts particularly from geological surveying or mapping of the sea floor and to formulate self regulation of whale watching to reduce tourist disturbance. The sanctuary has been proposed to be included

in the list of the Specially Protected Areas of Mediterranean Importance (SPAMI) in the Protocol of the Barcelona Convention (Article 17). When this happens, all provisions for the Sanctuary for protection of marine mammals will be binding on all parties of the Barcelona Convention and not just on the three range states.

Three areas have been identified as candidate Special Areas of Conservation (cSAC) for bottlenose dolphins in the Mediterranean Sea, based on long-term studies: the Strait of Gibraltar; the area around the Seco de los Olivos sea mount; and the area surrounding the Island of Alboran (Cañadas *et al.* 2004). An additional site covering the northern half of the Alboran Sea and the whole Gulf of Vera (Economic Exclusion Zone of Spain) was proposed as a SPAMI for the conservation of all cetacean species present in the area (Cañadas *et al.* 2004).

Other cSACs for bottlenose dolphins include the Moray Firth (Scotland, UK), southern part of Cardigan Bay (Wales, UK), the Shannon estuary (Ireland) and the Sado estuary and surrounding marine area (Portugal).

1.2 CROATIA

Following the death of Marshall Tito and with the fall of communism throughout Eastern Europe, the Yugoslav federation began to crumble. Croatia held its first multi-party elections since the Second World War in 1990 and the Croatian nationalist Franjo Tudjman was elected as President. One year later, the Croatian people declared independence from Yugoslavia and tension between Serbian and Croatian people within Croatia rose. One month after Croatia declared independence civil war erupted. The war officially ended only in December 1995 with the Dayton/Paris Peace Agreement, under

which a mutual acceptance of boundaries was sanctioned by all ex-Yugoslavian Countries (Commission of the European Communities 2004).

The Republic of Croatia extends over 56,594 km² of land and 31,067 km² of sea, with a total number of inhabitants of 4,443,000 (Central Bureau of Statistics 2004). The coast of the mainland stretches 1,777 km, but including the 1,185 islands and islets this figure jumps to 4,000 km (Fig. 1.2).

Croatia relies on tourism around the Adriatic Sea as its main source of international income. Development of tourism had been rising steadily from the early 1980s up until the war; however the infrastructure to support it has lagged behind. From an environmental standpoint, for example, much of the sewage and solid waste disposal is inadequate and still urgently requires upgrading, in cities (Massoud *et al.* 2003) as well as on islands (Island Development Centre 1997, Filipić and Starc 1998). The country still has a socialist oriented economy with heavy state ownership and control and this does not help a prompt revival of tourism (Croatia Tourism Cluster 2003).



Figure 1.2 - North and Central Adriatic Sea and sub-regions: Kvarner, Kvaneric, including Krk, Rab, Cres, Losinj and Pag islands. Refineries, petrochemical plants and oil terminal facilities are at Omišalj, Martišćica, Raša, and Rieka.

1.2.1 Protection and management of cetaceans in Croatia

The Constitution of the Republic of Croatia (Official Gazette No. 8/98) legally defines all components of natural resources as being of interest for the Republic and deserving its special protection. The Declaration on Environmental Protection in the Republic of Croatia (Official Gazette No. 34/92) states the initial terms for establishment of efficient environmental and nature protection in accordance with economic development using the principles of sustainable development.

Cetaceans have been strictly protected under Croatian law since 1995 (Official Gazette No. 31/95). Any research activity on protected species requires permission by the competent ministry (currently the Ministry of Culture). Prior to that, direct takes were not uncommon and for about 30 years they were actually supported by law. This was due to the perception that dolphins were competing with fisheries and, as such, rewards were paid for each animal killed (Holcer 1994, Bearzi *et al.* 2004). Even though after the mid-1960s the policy that resulted in those culling campaigns ceased (Bearzi *et al.* 2004), the habit of killing dolphins lasted until protection.

Since the early years of the Croatian Republic the attitude towards populations of dolphins has changed considerably. This change was demonstrated in the above mentioned Law for Nature Protection (1994), the Rulebook for the protection of all species of marine mammals (1995) and the subsequent “National Strategy and Action Plans (NSAP) for the Conservation of Biological and Landscape Diversity of the Republic of Croatia” (Official Gazette No. 81/99). The NSAP states that *‘particular emphasis will be placed on the protection of species listed as Endangered on a global, European or national scale’*. The NSAP outlined the need for the establishment of protected areas for all species of dolphins inhabiting Croatian waters and for the support of exhaustive research programmes. Croatia has shown the same attitude to

conservation internationally, becoming party to various international conventions relevant to cetacean protection (Table 1.3). In 2000 the Ministry of Environmental Protection and Physical Planning launched a project entitled *The Red Data Book of the Republic of Croatia*, which was resumed by the State Institute for Nature Protection after its foundation. In this *Red Data Book* the bottlenose dolphins is listed as *Endangered*.

Table 1.3 - Status of signature/ratification of relevant international agreements

ACCOBAMS	SPA	Barcelona	Bern	CMS	CBD	CITES	Ramsar
R/2000	S/1995	Suc/1991	EF/2000	EF/2000	R/1996	EF/2000	EF/1991

EF: Entry into Force; R: Ratification; S: Signed; Suc: Succession from former legislation (ex-Jugoslavia).

Source: UNEP RAC/SPA. 2003. Sixth meeting of National Focal Points for SPAs. Mediterranean Action Plan. Marseilles, 17-20 June 2003. UNEP(DEC)/MED WG.232/13. UNEP RAC/SPA, Tunis.

Prior to the legal protection of cetaceans, in 1993 a small portion of the Kvarnerić was proposed as a Special Dolphin Reserve based on data collected by the Adriatic Dolphin Project (ADP) (Bearzi *et al.*, 1993). This proposal was later incorporated into the Cres-Lošinj Management Plan (Island Development Centre 1997); however, the Plan was never implemented due to the political upheavals in the region. Subsequently the Blue World Institute for Marine Research and Conservation (*Plavi Svjet Institut*) prepared a new proposal based on the previous draft and new data (Mackelworth *et al.* 2002b, Mackelworth *et al.* 2003). This new proposal was accepted, in principle, by the local government and the Ministry of Environmental Protection and Physical Planning. In 2002, the Ministry took preliminary action by co-financing the project on “*The identification of critical habitats and the analysis of management procedures for the future Lošinj-Cres marine protected area*”, thanks to a bilateral research programme

funded by the Department for International Cooperation for the Environment and Development of the Principality of Monaco.

A section of this project was developed within this thesis (Chapter 3). In 2003 the Croatian Focal Point for RAC/SPA initiated the planning for the creation of a Marine Protected Area (MPA) for cetaceans in the Lošinj-Cres archipelago (UNEP RAC/SPA 2003). This plan came from a bilateral project for evaluation of some area of the Cres-Lošinj archipelago as a potential marine reserve important for dolphins and other protected species, financed by the Principality of Monaco.

Based on all this work, last summer the State Secretary of the Ministry of Culture of the Republic of Croatia declared the establishment of the Lošinj Dolphin Reserve (Ministry of Culture, Republic of Croatia, UP/I-612-07/06-33/676, 532-08-02-1/5-06-1, 26th July 2006). The area (<http://www.blue-world.org/MPA/>) - covering 526 square kilometres - is protected under the Croatian Law on nature protection as “Special Zoological Reserve for bottlenose dolphins (*Tursiops truncatus*)” and as such is subject to the strictest type of protection regime. Initially, the area receives preventive protection by inhibiting the development of any new human activities, for a maximum of three years. This will allow the establishment of a management body and the preparation of a management plan for the permanent Reserve. After this period the designation will become permanent through a Decree of the Government.

However, the recent shift of the competence for nature protection from the Ministry of Environment to the Ministry of Culture in 2004 appears to be counter to common practice in EU Member States (Commission of the European Communities COM(2004) 257 final). This shift could also create difficulties in the implementation of this Special Zoological Reserve, in terms of competency and jurisdiction.

1.3 THE KVARNERIĆ BOTTLENOSE DOLPHIN POPULATION:

BACKGROUND INFORMATION

Between 1987 and 2000 the Kvarnerić bottlenose dolphin population, comprising 100 to 150 individuals, was regularly studied by the Tethys Research Institute in the Kvarnerić Sea (Fig. 1.2). After 2000 the coordination of this research programme was passed to Blue World Institute, a local NGO specifically founded for this purpose. This long-term study still continues.

Available scientific information prior to this study on the Kvarnerić bottlenose dolphins comes from a few studies that can be summarised in the following paragraphs.

1.3.1 Distribution and habitat use

Bearzi *et al.* (1997) studied this sub-population between 1987 and 1994, photo-identifying up to 106 animals. Many of these were re-sighted on a regular basis, indicating a high level of year-round site fidelity, although their range was considered to be greater than the chosen study area. Rough estimates of dolphin density in this area based on the time taken to find a dolphin were highly variable (mean=141 mins; n=225, SD=144.1; range 1-1,139). Groups averaged 7.4 individuals, with a mode of 2. Bearzi *et al.* (1997) suggested that the social organisation of this dolphin community was highly flexible, possibly as an adaptation to environmental changes as well as a limited and variable availability of prey. Group fluidity was measured by these authors as the duration of 'sets', "*each set being determined by the joining or leaving of the group by one or more individuals*" (Bearzi *et al.* 1997). Little if any evidence of shark predation was found (Bearzi *et al.* 1997). Bearzi and Notobartolo di Sciara (1993) estimated the 'average' dolphin's geographic ranging capability at 543 km² in 24 hours.

1.3.2 Behaviour

Within the same time frame the diurnal behaviour of the Kvarnerić bottlenose dolphin population was observed (Bearzi *et al.* 1999). A 3-min behavioural sampling protocol was applied. The behavioural budget showed a predominance (about 80%) of activities characterized by long (>30 s) dives, considered to be largely related to foraging or feeding. Foraging near the surface was rarely observed. Dolphins were observed following bottom-trawlers in 4.6% of samples (Bearzi *et al.* 1999). Groups engaged in feeding-related activities were significantly smaller than groups that were travelling or socializing. The behavioural flexibility found in this bottlenose dolphin population was suggested as a strategy to cope with shifts in the environmental conditions in the northern Adriatic Sea (Bearzi *et al.* 1999). Bearzi *et al.* (1999) suggested that the high proportion of time consistently devoted to feeding-related activities, as compared to other areas, indicated that food resources in the Kvarnerić were not only highly variable but also depleted. However, their definition of “feeding-related activities” (any 3-min behavioural sample containing at least one dive longer than 30 s) suggests that caution should be exercised for at least two reasons: 1) a 30 s dive cannot be considered as a feeding-related dive for the Kvarneric bottlenose dolphin population (Fortuna 1996, Fortuna *et al.* 1996, Fortuna *et al.* 1998), particularly in the context of the physiographic characteristics of this area (generally with water deeper than 50 m), coupled with bottlenose dolphin food preferences (see Section 1.3.3); 2) comparing behavioural budgets of populations that inhabit physiographically different ecosystems may lead to wrong interpretations. This is especially true when the criteria used to define behavioural categories were designed for a population living in waters shallower than 10 m.

Physio-ecological aspects of respiration patterns of individual bottlenose dolphins have been analysed, in order to detect the possible relationships between energy expenditure

and foraging activities (Fortuna 1996, Fortuna *et al.* 1998). The distribution and averages of dive intervals changed significantly during different behavioural states. A variety of respiration patterns was observed. Two were defined as the most common and general: type A - characterised by a sequence of clustered short dives (6-10 s) followed by a long dive (136-248 s) - was considered a feeding-related pattern; whilst type B - a sequence of regularly spaced respirations (between 25 and 75 s) – was considered an expression of displacement behaviour. Within these general patterns, ventilation rates were found to differ significantly in relation to behaviour, increasing from ‘Following a fishing boat’ through ‘Dive-Travelling’ to ‘Diving’, the supposedly most energetically expensive behaviour category. These differences seemed to show the existence of various foraging strategies with potentially different energetic costs (Fortuna *et al.* 1998).

1.3.3 Diet

Feeding habits of local bottlenose dolphins are partially known from analysis of the contents of 11 stomachs (Miokovic *et al.* 1998, Stewart 2004, Fortuna unpublished data). Species found included conger eel (*Conger conger*), hake (*Merluccius meluccius*), pandora (*Pagellus* spp.), horse mackerel (*Trachurus* spp.), Bogue (*Boops boops*), common two banded seabream (*Diplodus vulgaris*), red mullet (*Mullus barbatus*), gilthead seabream (*Sparus auratus*), European barracuda (*Sphyraena sphyraena*), forkbeard (*Phycis phycis*), squid (*Loligo vulgaris*), octopus (*Octopus vulgaris*) and cuttlefish (*Sepia officinalis*). A possible shift in prey species from hake to *Trachurus* spp was found between “1995-2000” and “2001-2005” datasets (Fortuna unpublished data, Stewart 2004).

1.3.4 Growth and reproduction

Bearzi *et al.* (1997) proposed summer as the peak calving season. Preliminary information on the growth rates of bottlenose dolphins from the Croatian Adriatic showed an estimated age at maturity of 12 years and an estimated length at birth of 97 cm, obtained from fitting the Gompertz equation using the Fishery Science Application Program (Pribanic *et al.* 2000). This age-length curve was determined from 20 bottlenose dolphins (12 females, 7 males and one of unknown sex) collected in the Adriatic in the period 1990 – 1997 (Pribanic *et al.* 2000).

1.3.5 Skin abnormalities, deformities and injuries

In 1997-98 a detailed analysis of skin abnormalities, deformities and injuries in bottlenose dolphins around the Kvarnerić was carried out (Wilson *et al.* 1999a). Up to 26% of individuals appeared to have no lesions at all, whilst others displayed up to four types. Skin damage from physical injury was a very obvious feature in this population. Physical injuries were very common compared to the Moray Firth (Scotland, UK) animals. Up to 85% of Adriatic dolphin dorsal fins were nicked and 89% of backs were raked. In some individuals, the lesions covered up to 37% of the skin

In a world-wide comparative study, carried out on ten different bottlenose dolphin populations, Wilson *et al.* (1999a) confirmed that dolphins of the Kvarnerić showed the highest severity of injuries and one of the highest prevalence of injuries. These two characteristics may be because Kvarnerić bottlenose dolphins are highly aggressive with conspecifics (as suggested by the injury rate), because repigmentation are lower and healing rates higher than in other populations, and because this population is, on average, composed of older individuals. The high prevalence and severity of injuries makes this population ideal for photo-identification studies.

1.3.6 Local fisheries, fish resources and potential overlaps with bottlenose dolphins

Small-scale coastal fishing along the Croatian coast of the Adriatic is believed to be under great pressure, mainly because of overfishing by larger vessels (AdriaMed 2005). Unfortunately, the level of exploitation is unknown as catches of the coastal fishing gears are not recorded accurately, but it is considered to be higher than total allowable catch (AdriaMed 2005). Data on fish resources is even scarcer for this archipelago. This paragraph summarises the available information. It becomes apparent the need for focused and more intensive research effort in the field of fishery science and fish biology within Kvarner and Kvarneric, in order to help improving conservation of both, the bottlenose dolphin and local ecosystem.

The available official fishery statistics, prepared by the Institute of Oceanography and Fisheries (Croatian Environmental Agency, http://baza.azo.hr/projekt_more/index.htm, first entered on 18 January 2005) for the area that includes the Kvarnerić, show that there has been no increase in total catch in the past five years, despite an increase in the size of the fleet and the average fishing power. Most fish species have declined, especially *Mullus barbatus* and *Pagellus erythrinus*, but small pelagic fish species have increased. This seems to be reflected in the Kvarnerić bottlenose dolphins' stomach content analysis (see Section 1.3.3). Because of the methodology generally used to compile this type of information (e.g. landings data provided by fishermen), the reliability of these statistics is often considered questionable and partial, especially in absolute values for total catches as, for example, discards quantity is not evaluated. Nevertheless, data prepared by the Institute of Oceanography and Fisheries forms the only available official fishery statistics and is, therefore, used here as in indicator.

Taylor (1998) conducted a preliminary study of the local small scale fishery in order to assess its status and its interaction with the dolphin population. He found that there were

477 registered professional fishermen on the Lošinj-Cres archipelago in 1990, and that all boats were privately owned. By 1996 there were 190 registered fishing boats in Mali Lošinj, including 18 trawlers.

Bottom beam trawlers exploit demersal species such as hake (*Merluccius merluccius*), whiting (*Merlangus merlangus*) and various flatfish. Trawling areas and their relation with dolphin presence are shown in Chapter 3. Trawling using heavy tickler chains (to scare fish up from the seabed) has probably caused lasting damage done to the seabed (Hall 1999, Blanchard *et al.* 2004). Bottom set trammel nets are a particularly common method of fishing around the Lošinj-Cres archipelago; these are set in the evening and lifted during the morning of the next day. Catches in these nets are dominated by the fish families *Scorpaenidae*, *Labridae*, *Sparidae* and *Trigilidae*, but cephalopods, particularly *Sepia officinalis*, are also an important component of the catch. According to local fishery interviews, the size of *Merluccius merluccius* has been steadily decreasing (Taylor 1998, Mackelworth 2006).

'Ghost' nets are also an environmental problem in the area. It is estimated that every fishing vessel in the area loses between 0.5 and 1 km of net per year (Taylor 1998).

Bottlenose dolphins seem to be tolerated by fishermen of Lošinj; they are frequently seen performing feeding-related dives behind trawlers and out of trammel nets (Fortuna *et al.* 1996, Bearzi and Notarbartolo di Sciara 1997, Bearzi *et al.* 1999, Fortuna *et al.* 1998, Prihoda *et al.* 2006). In the Cres-Lošinj area there have been only three documented events of cetacean entanglement in operational or discarded fishing gear in the past 20 years. Other dolphin fatalities that can be attributed to fishing were caused by a deliberate shooting and the illegal use of dynamite fishing (Mackelworth 2006). Four such cases have been identified since 1997, one of which was a pregnant female (Stewart 2004, Fortuna unpublished data).

1.3.7 Boat disturbance and ambient marine noise

Boats may disturb cetaceans through their physical presence in an area and through the noise that they produce (Richardson *et al.* 1995, Jefferson 2000, Leung Ng and Leung 2003, Lemon *et al.* 2005). Noise from anthropogenic sources is now an inescapable fact of life for most cetacean populations worldwide. Such noises include seismic surveying, ship traffic, recreational craft, dredging activities, drilling, explosions, sonar noise and acoustic anti-predator devices (Richardson *et al.* 1995).

Nautical tourism in the Cres-Lošinj archipelago is particularly important for the economics of the area. As yet there has been no commercial dolphin watching activity in the archipelago. Rako (2006) investigated variation in underwater background noise or sea ambient noise (SAN) in the region using recordings of noise made at ten predefined sites, which she combined into Maximum, Medium and Control Impact Groups. Seasonal comparisons were based on the average RMS (Root Mean Square) values of recorded sound levels. Significant seasonal variations were found along the so-called Mali Lošinj-Rab 'highway' (see Fig. 2.1), at frequencies around 1 kHz. This area - belonging to the Maximum Impact Group - was characterised by the higher presence of large- and medium-size speed boats producing a level of noise from 1.5 to 3.5 times higher than, for example, that produced by motoring sailing boats.

The Medium Impact Group sites were in an area where dolphins are often sighted during the tourist period. It is the route normally used by excursion boats their way around the islands and by recreational boats. The total number of boats counted in the Medium Impact Group was significantly lower than in the Maximum Impact Group.

The low levels of sea ambient noise in the Control Impact Group could be connected to the increased sea depth compared to all other areas, as well as to its distance from the shores and bays of the main and small islands which are preferred by tourists.

Seasonal variations in SAN were related to the total number of boats scored during the recording sessions. In particular, there was a significant difference in the total number of boats observed in the summer and winter seasons for each of the three Impact Groups. Summer months also bring an increase in the number of large- and medium-size speed boats, the noisiest type of recorded boats. The highest number of these boats was recorded in the Mali Lošinj- Rab 'highway' (Maximum Impact Group). The southern part of the study area (Medium and Control Impact Groups) showed a significant increase in the number of trawlers, gillnetters and excursion boats between seasons.

In summary, Rako's study (2006) demonstrated a strong season-dependent variation in SAN between Impact Groups. Anthropogenic sound is mainly generated by vessels moving through an area during the summer season, especially on the route connecting Mali Lošinj to Rab.

The main increase in SAN was at frequencies around 1 kHz. It is not obvious what effect these sounds would have on bottlenose dolphins because existing audiograms are not reliable in this range due to technical limitations (Schultz *et al.* 1995, Janik 2000). Nevertheless, bottlenose dolphins do produce sounds in this frequency range when they are socialising (Schultz *et al.* 1995) and carrying out feeding-related activities (Janik 2000). In addition, many fish species are most sensitive in the range below 1-2 kHz and they could leave their feeding or spawning grounds in response to such sounds, with subsequent consequences for their long-term behaviour and survival (e.g., Engås *et al.* 1996, Popper 2003, Mitson & Knudsen 2003).

1.4 OTHER CETACEAN SPECIES

Many other cetacean species have been reported to occur in the North and Central Adriatic Sea including the fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaengliae*), sperm whale (*Physeter macrocephalus*), Cuvier's beaked whale (*Ziphius cavirostris*), false killer whale (*Pseudorca crassidens*), Risso's dolphin (*Grampus griseus*), striped dolphin (*Stenella coeruleoalba*) and common dolphin (*Delphinus delphis*). Sightings of these species are, however, rare and only bottlenose dolphins are regularly encountered in the region (Pilleri and Gahr 1977, Pilleri and Pilleri 1982, Bearzi and Notarbartolo di Sciara 1995, Bearzi *et al.* 1998, Affronte *et al.* 2003, Holcer *et al.* 2003, Lipej *et al.* 2004).

According to Brusina (1889) and Ninni (1904) (as cited in Bearzi and Notarbartolo di Sciara 1995), the common dolphin used to be the most common species in the Adriatic. Pilleri and Gahr (1977), as well as Pilleri and Pilleri (1982) noted a big decrease in common dolphins compared to the previous 40 years, and today it is considered to be rare in the region (Bearzi *et al.* 2004).

In the study area, only bottlenose dolphins, striped dolphins and common dolphins have been encountered, the last two species being rare or occasional species (Bearzi and Notarbartolo di Sciara 1995, Bearzi *et al.* 1998).

1.5 AIMS OF THIS STUDY

This work represents the first effort to study the dynamics of a Mediterranean bottlenose dolphin population in a systematic way, in order to learn more about its ecology and

conservation status. All analyses were based on a dataset collected during an ongoing long-term study between 1995 and 2003. This dataset is obviously the fruit of extensive collaborative work, but I was personally in charge of the fieldwork between 1995 and 2000. The remaining years of data were collected with the substantial involvement of the following people: Drasko Holcer (Croatia), Peter Mackelworth (UK), Annika Wiemann (Germany) and a number of field assistants. Various practical and procedural reasons limited the analyses presented here to this specific timeframe; however, other data series exist for this population (1987-1994 and 2004-present). Ultimately all the data series will be pooled in order to address questions that arise from the present work, to cross-validate some of the findings and to extend certain analyses.

Given the current status of the MPA proposal (sections 1.2.1 and 7.4), the following topics were considered to have a high priority for this thesis:

1. The identification of critical factors affecting the distribution and habitat use of bottlenose dolphins of Kvarnerić (Chapter 3);
2. The analyses of survival and reproductive rates (Chapter 4);
3. The estimation of abundance and trends in abundance (Chapter 5); and
4. The analysis of population viability (Chapter 6).

The existing MPA proposal (Bearzi *et al.* 1993, Mackelworth *et al.* 2001, Mackelworth *et al.* 2002b) requires a specific analysis of available data in order to identify preferred or unsuitable habitat for the bottlenose dolphins, and the factors behind any such selective behaviour. In Chapter 3, the relationships between presence/absence of dolphins and six topographic and anthropogenic factors are explored. The ultimate aim

of this analysis is to provide information that could indicate possible management mechanisms, such as zonation and the identification of practical rules to regulate anthropogenic activities within the proposed MPA. Analyses and results of Chapter 3 have been developed within the framework of a bilateral programme between the Croatian Ministry of Environment and Department for International Cooperation for the Environment and Development of the Principality of Monaco (Research Project on “*The identification of critical habitats and the analysis of management procedures for the future Lošinj-Cres marine protected area*”).

Capture histories of well-marked bottlenose dolphins were used to estimate survival, emigration, and reproductive rates (Chapter 4) and abundance (Chapter 5) with a threefold aim:

- 1) to provide baseline ecological information on the dynamics of this population;
- 2) to produce *ad hoc* input data for a Population Viability Analysis (Chapter 6),
and
- 3) to inform some of the conservation objectives, management actions and monitoring activities that should be contained in National or local Conservation Plans for bottlenose dolphins (Chapter 7).

CHAPTER 2: GENERAL MATERIALS AND METHODS

2.1 CROATIAN WATERS OF THE NORTH-EASTERN ADRIATIC SEA

2.1.1 The archipelago

The sea around the Croatian islands of the north-eastern Adriatic Sea can be divided into two main areas: the inshore and archipelagos waters (including Kvarner bay and Kvarnerić) and the open sea to the south-west (Fig 1.2). The coastal zone itself is mainly rocky, composed of cretaceous limestone with some Holocene sand deposits. The marine environment around the islands is affected by the meteorological and hydrographical regimes of the northern and central Adriatic, with an average tidal range of around 80 cm; under exceptional circumstances this may reach 200 cm (Island Development Centre 1997).

The coast of the eastern Adriatic is generally underdeveloped compared to the western Italian coast. However the northern part of Rijeka Bay has been one of the most heavily industrialised coasts in this region. The north-west corner of Bakar Bay was representative of this, having until 1997 a coke plant, petroleum terminal, an iron ore and coke loading wharf (Island Development Centre 1997, see Fig. 1.2). The main centres of population along the coast are Rijeka, Opatija and Pula. In all these places tourism swells the numbers in summer, thereby increasing the amount of land based pollution in the coastal area (Croatia Tourism Cluster 2003).

The northern Adriatic is potentially particularly susceptible to contamination due to its relatively low average depth, slow water exchange and inputs of contaminated waters from the rivers Po and Adige. Although the western side of this sea is known to be highly polluted (Degobbis *et al.* 1986, Limić and Valković 1996, Tankere and Statham 1996) most of the north-eastern side has been evaluated as either “unpolluted” or moderately polluted (four sites all near the main cities) (Bihari *et al.* 2004).

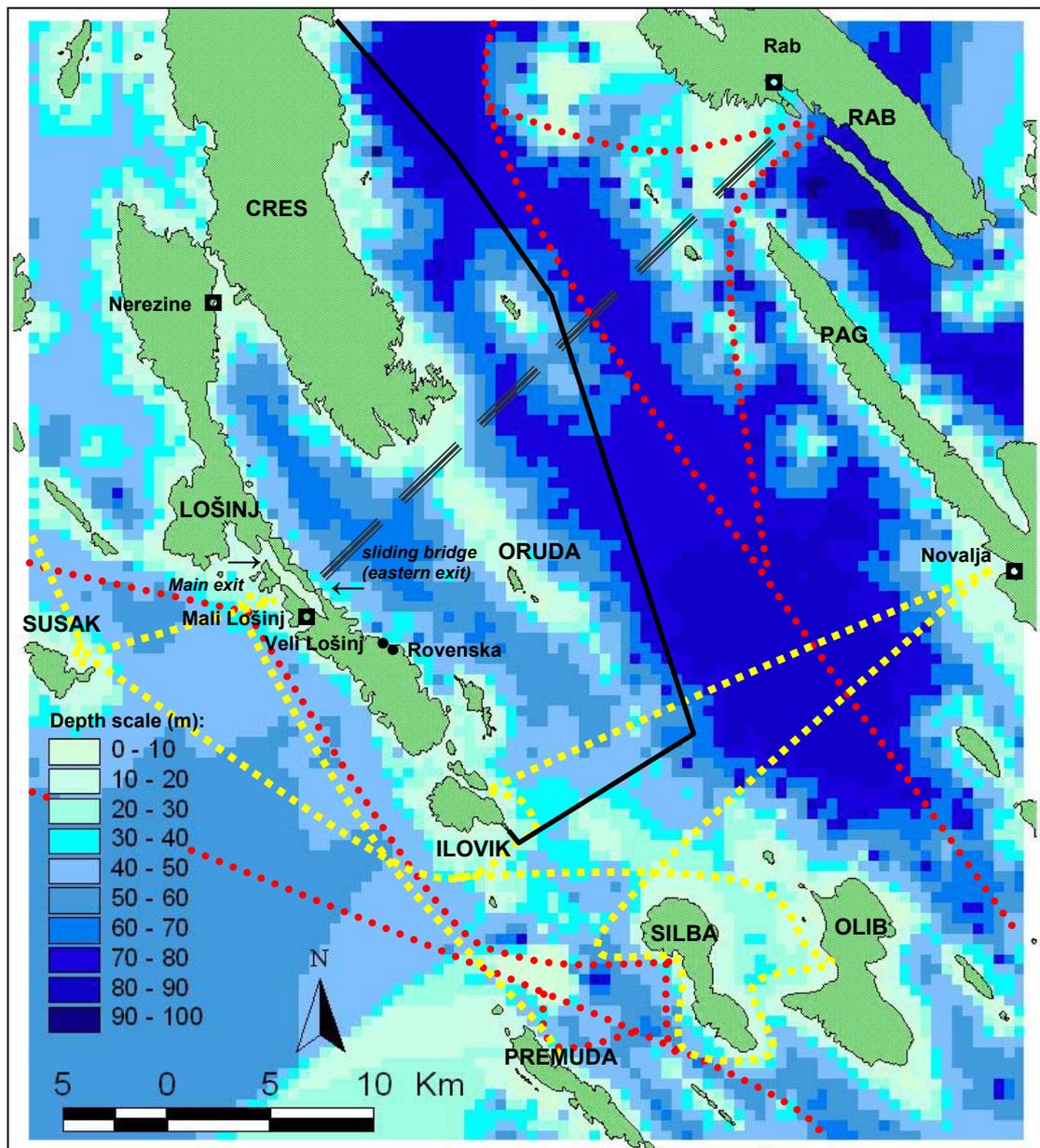


Figure 2.1 - Study area, 0.25 km² depth grid (scale categories in metres), proposed Marine Protected Area's boundaries (black line), local shipping routes (international and national ferries and hydrofoils routes in red and local ferries in yellow) and the Mali Lošinj-Rab recreational boats highway (triple dashed black line)

2.1.2 The study area

The study area (>2000 km²; Fig 2.1) is located within Kvarner Bay, in a region called Kvarnerić (Fig. 1.2). It is characterised by the presence of several islands and islets, encompassing a wide range of marine habitats, including rocky shores, submerged reefs, *Poseidonia oceanica* meadows and mud seabed. The maximum depth is around

119 m, but on average ranges between 50 and 80 m with an average salinity of 37.4 psu (grams of salt per litre of solution) (Kourafalou 2001). Mean quarterly Sea Surface Temperatures (SST) and the wind speeds (w), measured in Mali Lošinj between the 1966 and 1992, are summarised in Table 2.1.

Table 2.1 – Sea surface temperature and wind speed in Mali Lošinj*. Key: SST=Sea Surface Temperature; W=wind speed.

<i>Period</i>	<i>SST (°C)</i>	<i>W (ms⁻¹)</i>
January - March	12.0	5.6
April – June	16.9	4.8
July - September	23.1	3.1
October - December	16.9	5.3
* derived from Supić and Orlić 1999		

2.2 ANTHROPOGENIC PRESSURE

The Kvarner region (Fig. 1.2 and Fig. 2.1) is affected by many human activities that may detrimentally influence its marine and terrestrial ecosystems. Among these are: industrial maritime transport, shipbuilding, oil refineries, oil terminals, power stations, cement industry, tourism and fisheries. The oil industry, maritime transport and tourism are described below.

2.2.1 Oil industry

The oil industry is the main land-based source of oil pollution in the Kvarner Bay where the refinery and petrochemical plants, and oil terminal facilities are located (Fig. 1.2). Hot spots are: Raša Bay, Rijeka-INA Oil Refinery, Rijeka Port, Martinšćica Bay with "V. Lenac" Shipbuilding industry, Urinj-INA Oil Refinery, Bakar Port, Omišalj - Oil

Terminal and Omišalj - Petrochemical Port. Moreover, there are additional sources of pollution from the ballast water of petrol-tankers and accidental spillage because adequate on-shore reception facilities do not yet exist (UNEP PAP/RAC. 2002). The ports located in the Kvarner Bay have a total yearly turnover of about 9 million metric tonnes of the whole cargo, with crude oil and oil products contributing more than 6 million tonnes (UNEP PAP/RAC. 2002).

2.2.2 National and local ferries and hydrofoils

All of the populated islands are linked with the mainland and other islands by ferry services. Two of them are also connected to the mainland with bridges (Krkk and Pag islands; see Fig 1.2). During the summer, the frequency of ferry operations usually increases and fast hydrofoil services are regularly added. The summer sailing schedule operates from the end of May to the end of September. Long distance ferries cross the area 10 times per week (up to two per day). At least three boats operate, carrying between 900 and 1500 passengers per trip. The Zadar-Rijeka hydrofoil runs twice per week. The Lošinjska Plovidba Company also runs seven large cargo vessels out of Mali Lošinj to various Mediterranean ports. In addition to these large-scale maritime activities, locally a seasonal boat rental operation has recently flourished. Shipping routes within the study area are shown in Fig 2.1; recreational routes are excluded, as they are not fixed.

2.2.3 Tourism

During the 1970s and 1980s the coastal areas and islands of ex-Yugoslavia (now located in Croatia) began to grow economically and demographically mainly due to tourism (Filipic and Starc 2002). Growth was extremely rapid and did not consider any sustainable development. For example, the notion of “island carrying capacity” or “rational long-term usage of island resources” appeared for the first time in “The Social

Agreement on Development Policy for the Adriatic Islands” in 1986 (Filipic and Starc 2002). In 1991 the regional war started, halting any further attempt in this direction (Filipic and Starc 2002). The occurrence of periodic political instability and its associated negative perception are known to have decimated the tourism industries of several destinations world-wide, including Croatia (Seddighi *et al.* 2001). However, the war in Croatia intensified rather than caused the crisis in Croatian tourism, particularly on the islands, which had already begun at the end of the 1980s (Benic 2000). In 1995, following the war, due to the relatively cheap prices and unspoiled locations, Croatian tourism experienced a quick and strong re-growth at an annual National rate of over 12% (Filipic and Starc 2002, Stučka 2002, Croatia Tourism Cluster 2003). Yet again there was an absence of planning for a sustainable development (Croatia Tourism Cluster 2003). As 77% of tourism is concentrated in a short summer season (June–August), if not planned and managed in an orderly manner it may put Croatian natural, cultural, and community resources at risk (Croatia Tourism Cluster 2003). This potential threat is exaggerated by the fact that 45% of Croatian cities lack wastewater treatment and where treatment exists it is normally no better than primary (UNEP/MAP/WHO 2000). This is also true for almost all islands of the Croatian archipelagos (UNEP/MAP/WHO 2000).

Locally unmanaged tourism means increased: maritime traffic, recreational boat traffic and all the related pollution (for example, inappropriate sewage system and solid litter at sea).

2.2.4 Fishery

Small scale coastal fishing along the Croatian coast of the Adriatic is believed to be under great pressure, mainly because of overfishing possibly caused by industrial fisheries. Unfortunately, the level of exploitation is unknown as catches of the coastal

fishing gears are not recorded accurately, but it is considered without doubt to be higher than total allowable catch (AdriaMed 2005). More details are given in Chapter 1. The situation in the Cres-Lošinj Archipelago is believed to be similar (Taylor 1998).

2.3 DATA EXTRACTION, COLLECTION METHODS AND PHOTO-ID PROCESSING

2.3.1 Geo-referencing maps

Nautical maps, issued by the Croatian Hydrographical Institute of Split, were geo-referenced by using appropriate image-to-world transformation files (*.JPGW), containing the image transformation information for the software ArcView 3.2 GIS (Environmental Systems Research Institute [ESRI], USA). Such files allow ArcView to convert the image coordinates to real-world coordinates. Each World file includes six parameters referring to pixel (column and row) and GPS coordinates (northing and easting) of two given points on the map, preferably taken on the diagonal (point 1 and 2 in Fig 2.2).

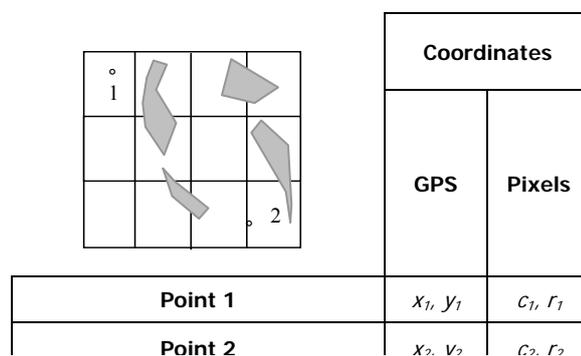


Figure 2.2. A hypothetical map with two chosen georeferencing points (x is easting, y is northing, r is the pixel row number and c is the pixel column number)

Coordinates of Points 1 and 2 are calculated as follow:

$$x = Ac + Br + C \quad \text{Equation 2.1}$$

$$y = Dc + Er + F \quad \text{Equation 2.2}$$

where x and y are the calculated x - and y -coordinates of the pixel on the map; c and r are the column and row number of a pixel in the image; A is the x -scale (the dimension of a pixel in map units of easting); B , D are rotation terms (zero rotation in this case); C , F are translation terms (map coordinates of the centre of the upper-left pixel); and E is the negative of the y -scale (northing dimension of a pixel in map units). Specifically, given the example in Fig. 2.2,

$$A = \frac{X_2 - X_1}{c_2 - c_1} \quad \text{Equation 2.3}$$

$$C = x_1 - (A \times c_1) \quad \text{Equation 2.4}$$

$$E = \frac{Y_2 - Y_1}{r_2 - r_1} \quad \text{Equation 2.5}$$

$$F = y_1 - (E \times r_1) \quad \text{Equation 2.3}$$

From geo-referenced JPG images, coastlines and depths were then digitised. Bathymetry and coastline readings were re-projected into the Universal Transverse Mercator system to obtain maps (Fig. 2.1). The Spatial Analyst Tool (ESRI) calculated the values of the other selected parameters.

The bathymetry raster was transformed into a “depth sampling unit grid” made up of square cells of 0.25 km² size (500 × 500 m). Fig 2.1 also shows the 0.25 km² “depth sampling unit grid” from which all covariates were derived. The mean depth of each

cell was calculated by using a six neighbour Inverse Distance Weighted (IDW) interpolator. The IDW assumes that each input point has a local influence that diminishes with distance; hence, for each cell analysed, 6 points were used to weight its contained values. Cell size grids of 1 km² and 4 km² were adopted to assess the possible effects of using different spatial scales in analysis, referred to as GRID1000 and GRID2000 respectively. For each new grid size, all other variables were extracted by superimposing GRID1000 and GRID2000 over the original 0.25 km² depth grid and islands contour. New depth values were calculated as the average of values from the 0.25 km² depth grid, in each cell. The slope was measured as the difference between the minimum and maximum depth within each cell, divided by the distance between the points of maximum and minimum depth (m/km). A measure of the variability of the sea bottom was estimated by calculating the Standard Deviation (SD) of depth values from the depth grid (4 and 16 depths for GRID1000 and GRID2000, respectively). The distance to the nearest coast, marine petrol stations and areas of high recreational intensity, were calculated as the distance between those points and the centre of each cell. Trawling areas were defined with buffer areas of 500 m around positions of observed bottom working trawlers, collected during the study period. A given cell was considered within a trawling area when touched by any such buffer area.

2.3.2 Effort data

Data on bottlenose dolphins' distribution, abundance and behaviour were collected using boat-based surveys and photo-identification techniques, between April 1995 and October 2003. The duration of the research season varied annually, between February and October, due to the weather, political and budgetary factors. Given the original focus of the Adriatic Dolphin Project (analysis of population dynamics through photo-identification), the effort was carried out non-systematically. Although there was a conscious attempt to cover all parts of the study area each month, geographical

distribution of effort was strongly affected by: starting harbours (closer areas were surveyed more often than the borders of the study area), local weather conditions (for example, local patterns of daily wind variations) and frequency of dolphin encounters in specific areas that could have attracted our attention.

Surveys were carried out from two fibreglass keel inflatable boats, 4.70 m (1995-2000) and 5.85 m (2000-2003) long, powered by 4 stroke outboard engines (50HP and 90HP, respectively). Average searching speed varied between 15 and 30 km/h during these two periods. Surveys started from one of two harbours (Veli Lošinj and Rovenska), about 600 m apart. During surveys, a crew of 2-6 people (including at least 2 experienced researchers) scanned the horizon, from a standing position. Search effort was focused in a 180° forwards arc. The position of the boat was determined using two different GPS (Magellan Nav 100 Plus, until 2000, and Garmin GPS MAP 76 afterward), with error ranging between zero and 150 m. Data, time and coordinates were recorded at the beginning and the end of each survey and at any time a change in survey conditions or route occurred. Any other relevant information was also noted, such as position of working trawlers. Search conditions were considered “good” if the visibility was not reduced (no haze or fog) and Beaufort sea state was less than 3 (no white caps). Otherwise the conditions were described as “poor” and all related data were excluded from the analysis. For descriptive purposes and to conduct spatial analysis, navigation tracks were plotted by GIS ArcView software.

2.3.3 Sightings data

When dolphins were sighted, an “encounter” was initiated. At its beginning and end coordinates, time, search conditions, best estimate of group size, as well as the estimated age categories of the animals, were recorded. Initial positions of encounters

were plotted using GIS ArcView. The position of the research boat (within 50 m of the dolphin group) was assumed to be the position of the focal group.

We considered a group as any group of dolphins observed in apparent association, moving in the same direction and often, but not always, engaged in the same activity (Shane 1990). Dolphins were considered members of a focal group when they remained within a 200 m radius.

The presence of bottlenose dolphins behind trawlers was evaluated by stopping the boat at about 200-300 m from the trawlers' stern for a maximum of 5 minutes. We considered dolphins engaged in "feeding-related behaviour" behind trawlers, when they were performing sequences of long dives (about 3-5 min) followed by few ventilations, within 300m of the stern of a working trawler, and following its route (Fortuna *et al.* 1998, Bearzi *et al.* 1999).

Age was estimated by assigning the individual dolphins to one of the following four age classes, based on visual assessment of size, as compared to average adult size, colour, and behaviour:

- 1) **Newborn (N)**, a dark grey or brown individual 1/3 the length of an adult, with visible foetal stripes, uncoordinatedly swimming always beside an adult, presumably its mother;
- 2) **Calf (C)**, a light grey individual 1/2 the length of an adult, with often visible foetal stripes, always swimming close to its mother in a typical position just behind her dorsal fin;
- 3) **Juvenile (J)**, a light grey usually poorly scarred and rarely nicked individual 2/3 the length of an adult, always in the same group as its mother but not necessarily always swimming together;

Regardless of any difference that was noted in the field, in this thesis categories Calf and Juvenile were treated together (See Chapters 4 and 5).

- 4) **Adult (A)**, a dark grey individual, generally of length about 2.8-3.0 m, with scars on the body

2.3.4 Photo-identification and matching procedures

Photo-identification was performed following Würsig and Jefferson (1990). Photographs were taken using a Minolta 8000i AF camera with 80-200mm, f2.8 zoom lens and 64-100 colour transparency film.

When a group was detected the speed of the boat was reduced and the dolphins were approached. This manoeuvre was done avoiding sudden and erratic changes of speed or direction, to minimise disturbance. By gradually converging to their route at a shallow angle to their direction of travel, at the end of this manoeuvre our boat was proceeding at about 5-6 km/h parallel to the route of the focal group.

On each encounter dolphins were followed for a variable time, sufficient to attempt the photo-identification of all individuals. The photographer attempted to obtain 3-5 pictures of each dolphin, ideally showing both sides of the dorsal fin. Marks such as scars, notches, distinct nicks, tooth marks, holes, missing portions, lesions, on the dorsal fin of the dolphins, as well as the general shape of the fin were used as “natural tags”. In addition any other distinct mark on the body that could be useful in distinguishing individuals was taken into consideration. Some examples of characteristic photo-identification prints, showing typical marks and shapes are given in Fig. 2.3 and Fig. 2.5. Such marks or scars are likely to be produced by either harsh physical contact between individuals, predator attacks, collision with inanimate objects or human-interactions (e.g. cuts inflicted by boat propellers or fishing nets). Since animals acquire

such marks during their lifetime, mainly adults are recognisable. However, in this population sub-adults interact with each other or with adults and get tooth marks and very small nicks that in some cases allowed the tracking of their growth until they became definitely marked. Unmarked newborns, calves and juveniles were identified with reference to the mother, since they were normally accompanied in close association with her for about five years.

Some researchers have questioned if such marks are in fact permanent (Lockyer and Morris 1990), and there is little data on how long marks last. However it is believed that major wounds may last forever, with the caveat that any new marks may obscure identification, unless a good record of the evolution of the fins of identified dolphins is kept (Wursig and Jefferson 1990). In a comparison of epidermal lesions of ten populations of bottlenose dolphins worldwide (Wilson *et al.* 1999a), the Kvarnerić population had the highest severity of injuries and one of the highest injury prevalence rates. In this population a simple white scar lasts up to 13 months and can be very useful to track the evolution of the fin between different research seasons, in which time other major changes could occur.

During each sighting a “photo-identification sheet” was compiled, noting all necessary information (Table 2.2). Any useful notes on specific association patterns (for example, on different sub-groups or pairs) or general behaviour were also recorded. In order to assign a roll numbers to each sighting, a special “blank” was taken as “spacer” at the beginning of each roll and sighting. These pictures usually portrayed anything but dolphins and their content and number was carefully annotated on the form.

Table 2.2 – Data contained in the photo-identification sheet

- Date;
 - Initial and final time;
 - Chronological number of sighting: starting from the beginning of each year;
 - Initials of the photographer;
 - Total number of dolphins: best estimate;
 - Age classes: total number of individuals presents within the group divided by each age class;
 - Initial and final encounter position;
 - Number of roll;
 - Number of pictures;
 - Description of the picture: for example, a specific dolphin or pair or mother or a “blank”;
 - Field identification: names of dolphins identified in the field;
 - Notes.
-

Based on the field notes, once developed each slide was sorted chronologically and five fundamental details were transcribed on its plastic frame (Fig. 2.3): initials of the photographer (upper left-hand side corner), date (lower left-hand side corner), chronological number re-starting every year (upper right-hand side corner), number of sighting (lower right-hand side corner), and name(s) of identified dolphin(s) contained on each picture.

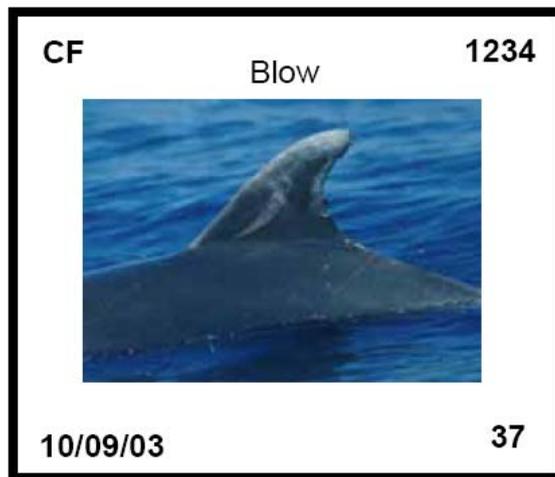


Figure 2.3 - Example of slides sorting codes

Only sharp slides were used for the matching procedure, which was performed on a light-table using an optical magnifying loupe. Photo of dorsal fins were “manually” compared to avoid double identities and provide a consistency with the past, existing *Adriatic Dolphin Project* 1990-1994 catalogue. Every time a match was found the photo was marked with the name of the dolphin and was filed back in the “sighting chronological catalogue”. Furthermore the best pictures of each identified individual were filed separately in an “individual photo-id archive”. Therefore two types of catalogue were used, the “sighting chronological catalogue” which was used to trace chronologically all the sightings of an individual and from where all the data for this study have originated, and the “individual photo-id archive” that contains the type specimen of each identified animal. This was periodically re-assessed to include the best and most recent photographs of individuals, ideally one from each side of the dorsal fin side for each year, in order to keep updating any possible changes in fin features (acquisition of new nicks or evolution of old ones) that the animals may develop.

If no matches were found between the unknown fin and the photos of the fins in the “individual photo-id archive”, the possibility of being a new non-identified dolphin was

considered. Before a dolphin was confirmed to be a new identified individual and assigned a name, all the photographs of the new dolphin's dorsal fins and other independent body marks had to be checked and compared with those of all the dolphins previously catalogued. Names were the key to tracking information on particular animals through time. Dolphins that could not get identified with certainty, having no major nicks but only scars, were only assigned a number and were filed separately from the individual photo-id archive. They were considered unmarked and not included in these analyses. In order to facilitate the matching procedure, drawings of both fin's sides for each dolphin, based on the most recent slides, were included in the individual photo-id archive (Fig. 2.4). Experience and time available were important factors in the accuracy of the matching procedures.

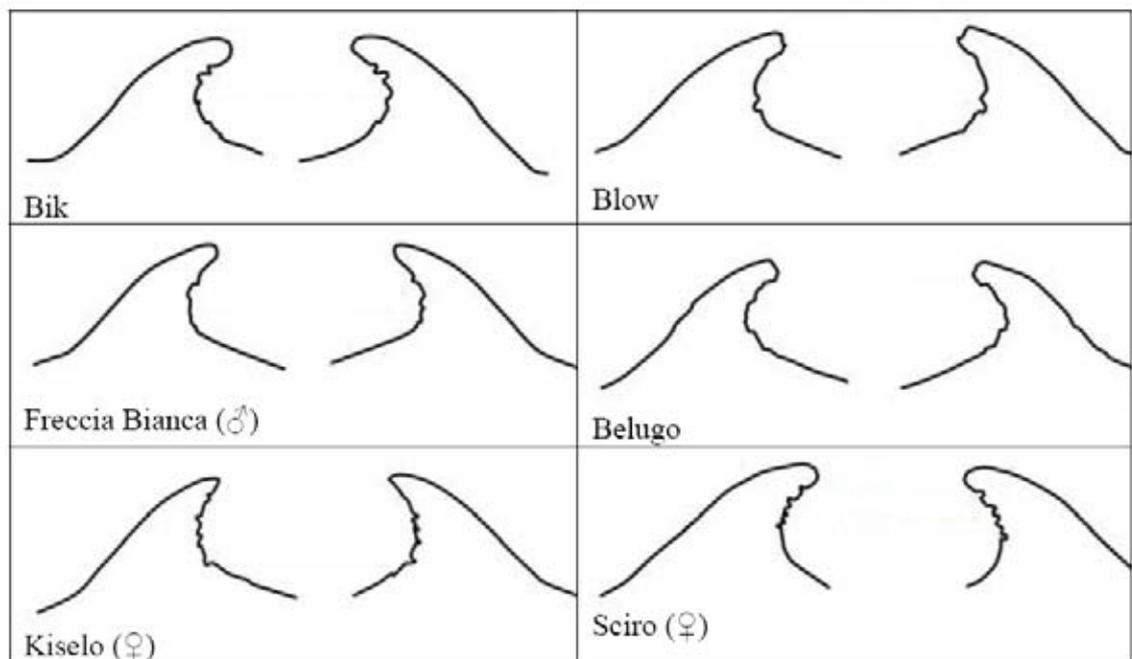


Figure 2.4 - Examples of trailing edges of different dolphins

Variations in photographic quality are unavoidable while attempting to focus on moving animals from a moving platform under differing light conditions. These variations cause

analytical problems. In fact, the inclusion of poor-quality photographs of well-marked individuals and exclusion of good-quality photographs of individuals with subtle identifying characteristics introduces biases into population analyses (Hammond 1986, 1990b). Therefore, we developed two quality categories (see Table 2.3 for their definitions) and restricted the analysis to good quality photographs. In addition, we developed three categories of fin marking: *Well Marked* (WM), *Poorly Marked* (PM), and *Unmarked* (UM) (see Fig. 2.5 for some examples). The severity and depth of wounds determines the period of time for which scars can persist and may be used for identification in bottlenose dolphins (Lockyer and Morris 1990). However, regular monitoring (at least annually) is required in order to avoid misidentifications due to mark loss or masking.

Table 2.3 – Photo quality categories

Good quality (GQ): pictures with the dorsal fin in focus, on the right angle (90°) and reasonable size (> 1/16 of the entire frame).

Poor quality (PQ): pictures include all pictures of unfocused and/or wrong angled dorsal fins, as well as well as photographs of too far individuals.

Different types of analysis were performed on different types of photo quality.

The age categories assigned during fieldwork were always checked during the matching procedure. Sex was also determined opportunistically from sequences of photographs of the genital area and dorsal fin of the same individual. Adult individuals that were consistently accompanied by a calf over several sightings/months/years were considered females.



Dante (WM)



Mush (WM)



Tac (WM)



Vivian (WM)



Debby (PM)



Benede (PM)

Figure 2.5 - Examples of fin markings categories of identified bottlenose dolphins: well marked (WM) and poorly marked (PM) individual

**CHAPTER 3: IDENTIFICATION OF CRITICAL FACTORS
AFFECTING THE DISTRIBUTION AND HABITAT USE OF
BOTTLENOSE DOLPHINS OF KVARNERIĆ (CROATIA)**

3.1 INTRODUCTION

The effectiveness of any management framework for conservation or protection depends on the ability to assess the main factors influencing the maintenance of a given population and to set achievable and measurable aims. These factors include the population status, the preferred habitats, and all factors – biotic and abiotic, natural or anthropogenic - that may either threaten or enhance a species' survival. Such a fundamental task is usually impossible to achieve in the short-term and can be expensive to accomplish, especially when the population highlighted for protection consists of an elusive top-predator, such as a whale or dolphin species. Marine ecosystems are complex and cryptic systems, for example, predator-prey interactions can be highly dynamic and are related not only to the characteristics of the species involved but also to the variation in a wide spectrum of oceanographic factors. As such, intensive inter-disciplinary research programmes are required to build accurate assessments of these systems. However this must be balanced against cost-effective means to turn nature protection from a theoretical exercise into effective wildlife population management.

As a result of a combination of conservation needs and the complexity of ecosystems, critical habitats or factors affecting the welfare of wildlife populations are often measured indirectly, by identifying indices or proxies. For example, oceanographic characteristics have an impact upon the movements of cetacean prey and can, therefore, be used as indicators for cetacean distribution. This has been demonstrated for environmental factors analysed singly or combined in habitat categories (Davis *et al.* 1998, Hooker *et al.* 1999, Baumgartner *et al.* 2001, Gregr and Trites 2001, Waring *et al.* 2001, Benson *et al.* 2002, Davis *et al.* 2002, Ingram and Rogan 2002, Moore *et al.* 2002, Cañadas *et al.* 2003, Bräger *et al.* 2003). With respect to the bottlenose dolphin, a few studies have investigated such connections at the local level (Kenney 1990, Shane 1990, Wells *et al.* 1990, Wilson *et al.* 1997, Barros and Wells 1998, Wood 1998, Rossbach and Herzing 1999, Allen *et al.* 2001),

shedding some light on correlations between their ranging patterns and biotic and abiotic features, including oceanographic, physical, atmospheric parameters and prey movements.

A strong influence on cetacean distribution can also be attributed to a diverse range of human activities which can either result in a degree of attraction (Pryor *et al.* 1990, Fertl and Leatherwood 1997, Fortuna *et al.* 1998, Bearzi *et al.* 1999, Chilvers *et al.* 2003, Read *et al.* 2003b, Sini *et al.* 2005) or, more often, avoidance (Irvine *et al.* 1981, Janik and Thompson 1996, Allen and Read 2000, Nowacek *et al.* 2001, Morton and Symonds 2002, Williams *et al.* 2002a and 2002b, Leung Ng and Leung 2003, Lemon *et al.* 2005, Sini *et al.* 2005, Bejder *et al.* 2006a,b). Human disturbance may or may not have significant consequences for the survival or fecundity rates of populations, as seen in the case of the Florida manatee (Langtimm *et al.* 1998) or South Pacific sperm whales (Evans and Hindell 2004). Hence an understanding of the true extent and nature of such disturbance must be a fundamental aim of any assessment of human activities (Gill *et al.* 2001), especially within a proposed or established Marine Protected Area (MPA).

When combining information from a wide range of substantially different variables, such as physical, biological and anthropogenic factors varying temporally and spatially, predictive models, which take into account uncertainties related to the ecosystem in question, may be preferred to experimental studies. Nevertheless, in open systems, the development of models that can accurately predict the presence or density of a cetacean species is neither a trivial nor an inexpensive task. Instead it is advisable to take a multidisciplinary approach that takes account of different perspectives, diverse ranges of information and at the same time maintains flexibility.

Several studies of this kind have been conducted to define critical habitats for the designation of MPAs, including candidate Special Areas of Conservation (cSAC) under the EU Habitats Directive, based on the distribution of cetaceans (Wilson *et al.* 1997, Hooker

et al. 1999, Ingram and Rogan 2002, Cañadas *et al.* 2003, Hastie *et al.* 2003b, Cañadas *et al.* 2005) in Canada, Ireland, Spain and the UK.

The main objective of this study was to determine the natural and anthropogenic factors that affect the distribution of bottlenose dolphins in the study area, and to use this information to identify areas that may be particularly important for the Kvarnerić population.

Such information will ultimately provide a science-based framework to implement a management proposal for the “Lošinj Special Zoological Reserve” for bottlenose dolphin conservation. The obtained results will also help in defining boundaries of the “Lošinj Special Zoological Reserve” and in implementing regulations on specific human activities such as recreational boating.

3.2 MATERIALS AND METHODS

3.2.1 Study area

The study area lies on the eastern side of the northern Adriatic continental shelf and extends for about 2,000 km² (Fig. 2.1). This side of the Adriatic is punctuated by channels, islands and islets, and submerged reefs and is characterised by rocky shores that drop abruptly to depths of up to 100 metres. The channels mainly have sandy or muddy bottoms. The water is oligotrophic and pollution from PCBs, DDT and other similar compounds appears highly localised and relatively low (Degobbis *et al.* 1986, Limić and Valković 1996, Tankere and Statham 1996, Kljaković-Gašpić *et al.* 2002). This area can be therefore considered as relatively pristine compared to a highly polluted sea, such as the Adriatic Sea (Kljaković-Gašpić *et al.* 2002, Bihari *et al.* 2004).

3.2.2 Data collection

Details of survey procedures and data collection are given in Chapter 2, sections 2.2 and 2.3.

3.2.2.1 Anthropogenic activities

To analyse the possible effect of human presence in the Kvarnerić, information on the number of boats registered at the two main Harbour Master offices in Mali Lošinj and Rab was collected. Additional data were gathered on tourism fluxes (annual number of nights spent by tourists in the archipelago) from the Tourist Boards of the City of Mali Lošinj, Rab and Pag. Data on trawling areas were also collected during our surveys, as described in Chapter 2, section 2.1.

3.2.3 GIS Data processing

Details on GIS data processing and the analysis used to extract covariate data are given in Chapter 2, section 2.1. In order to explore the effects of spatial scale on habitat preference modelling, grids cells of 1 km² and 4 km², referred hereafter as GRID1 and GRID4 respectively, were superimposed on the study area.

3.2.3.1 Encounter rates

Because survey coverage was not even across the study area, annual encounter rates were calculated in two ways:

1. ER₁: the annual average of cell encounter rates (encounters/sum of km covered in each cell) in good survey conditions. This procedure allowed the standardisation of the data used in the analysis that was collected during surveys of non-systematic effort.

2. ER_2 : the total number of encounters divided by the total number of km surveyed each year.

In both cases, only data from cells with an annual effort ≥ 1.414 km (diagonal of a 1 km² cell) was used.

3.2.3.2 Encounters behind working bottom trawlers and trawling areas

A particular procedure was applied when working bottom trawlers were encountered because dolphins have been observed following these vessels and diving for more than 6 min while following them (Fortuna *et al.* 1998). Whenever a trawler was observed, the research boat stopped for 4-5 min in its wake (off-effort), checking for the presence of dolphins. At each trawler position recorded, with or without dolphins, a circular buffer zone (500 m radius) was created. These buffer zones were superimposed on the grids (GRID1 and GRID4 - paragraph 2.31) creating maps of trawling areas (TRAWL) (see also paragraph 3.2.3.3 and Fig. 3.8).

An annual index of “exploitation” of working trawlers by the bottlenose dolphins was estimated as:

$$\text{Annual index of “exploitation” of working trawlers} = \frac{N_{ET}}{N_T} \times N_E^{-1}$$

Where N_{ET} is the number of encounters behind trawlers, N_T is the total number of trawlers observed annually and N_E is the total number of encounters.

3.2.3.3 Habitat categories: defining covariates

Data were available for three physical, one geographic and three anthropogenic covariates to be considered as possible factors affecting the distribution of bottlenose dolphins in the study area. These were: bottom depth (DEPTH), bottom variability (SD.DEPTH), slope

(SLOPE), distance from the nearest coast (DIST), distance from marine petrol stations of Mali Lošinj, Rab and Novalja (MAN.FIX) (see Fig. 2.1), distance from the route connecting the two main harbours (Mali Lošinj and Rab; Fig. 2.1), an area of high recreational boat transit intensity (MAN.MOV) [as shown by (Rako 2006)] and here termed the “marine highway”, and trawling area (TRAWL). Relevant data were extracted from nautical charts (Mercator projection, scale 1:50,000) issued by the Croatian Hydrographical Institute of Split, geo-referenced and projected into the UTM system for the analyses. See Chapter 2, section 2.1 for more details.

3.2.3.4 Habitat use modelling

In order to link bottlenose dolphin presence to the spatially-explicit explanatory covariates, sightings data were imported into a Geographic Information System. Analyses of the spatial distribution of dolphin groups and habitat use were carried out only on the geographical positions recorded at the beginning of each encounter.

Habitat usage was analysed by applying resource selection functions (Boyce and McDonald 1999, Boyce *et al.* 2002). Generalised Linear Models (GLM), multiple regressions that allow for non-normally distributed variables, were used. GLMs also assume a linear link relationship between response and explanatory variables which enables the analysis of bounded dependent variables, such as binary variables. The response variable modelled was the presence/absence of dolphins. GLMs were characterised by a *Binomial* family (presence/absence of dolphins) and a *Logit* link function.

GLMs were run backwards stepwise, using the AIC (Akaike Information Criterion) to select the model that received most support from the data. Scatter-plots of the standardised deviance residuals against the fitted values, which were transformed to a constant scale of the error distribution, and the variability explained by the model, were used to assess

model fit. A measure of the explained variability of the fitted model was calculated as the *null deviance* minus the *residual deviance* divided by the *null deviance*.

For terrestrial animals, habitat availability and habitat abundance can differ greatly (Allredge and Ratti 1986, Allredge *et al.* 1998). For bottlenose dolphins, assuming each cell within the study area was equally accessible to dolphins, habitat availability was assumed to be equal to habitat abundance. According to the definition of a resource selection function (Boyce and McDonald 1999), our GLMs modelled the proportion of habitat used by dolphins and provided predictive maps of encounter probabilities for the whole area.

Habitat categories for the GLM analysis were defined by splitting the range of values of each explanatory covariate into a given number of discrete, equally spaced bins. Habitat categories were represented by all possible combinations of the bins of these covariates.

The sampling unit was the grid cell. Sampling effort was defined as the number of times a cell was surveyed. Only those combinations with effort > 0 were used for the GLM analysis. An annual difference in the number of habitat categories was expected because of changes in annual survey effort. With this procedure, we were able to consider the effect of the explanatory covariates on the response variable (animal distribution), switching from a cell to a habitat category basis.

All data handling and statistical analyses were performed in R software (Version 1.5.0, 2002, <http://cran.r-project.org>).

3.2.3.5 Choice of the explanatory covariates and data sub-sets

The explanatory covariates considered were DEPTH, SD.DEPH, SLOPE, DIST., TRAWL, MAN.FIX, MAN.MOV, as described above. Interaction terms and non-linear terms were also considered. After inspection of the relationships between encounter rates

and these explanatory covariates, the cubic term of DEPTH (Figure 3.1) was introduced and MAN.MOV was replaced with its natural logarithm (\ln MAN.MOV) because the impact of the “marine highway” is assumed to decrease with distance. In addition, three interaction terms were added: DEPTH:SLOPE, DEPTH:DISTANCE, SLOPE:DISTANCE (Figure 3.2). SD.DEPTH was excluded from the set of explanatory covariates because it was never found to be significant.

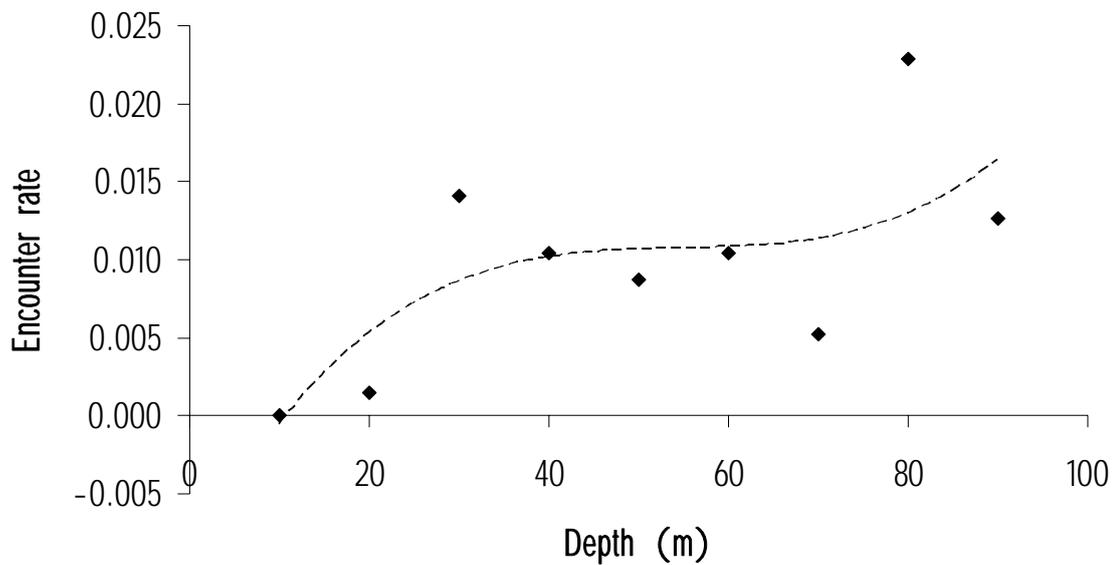


Figure 3.1 - Relationship between encounter rate (number of encounter/number of surveys per cell) and water depth (m)

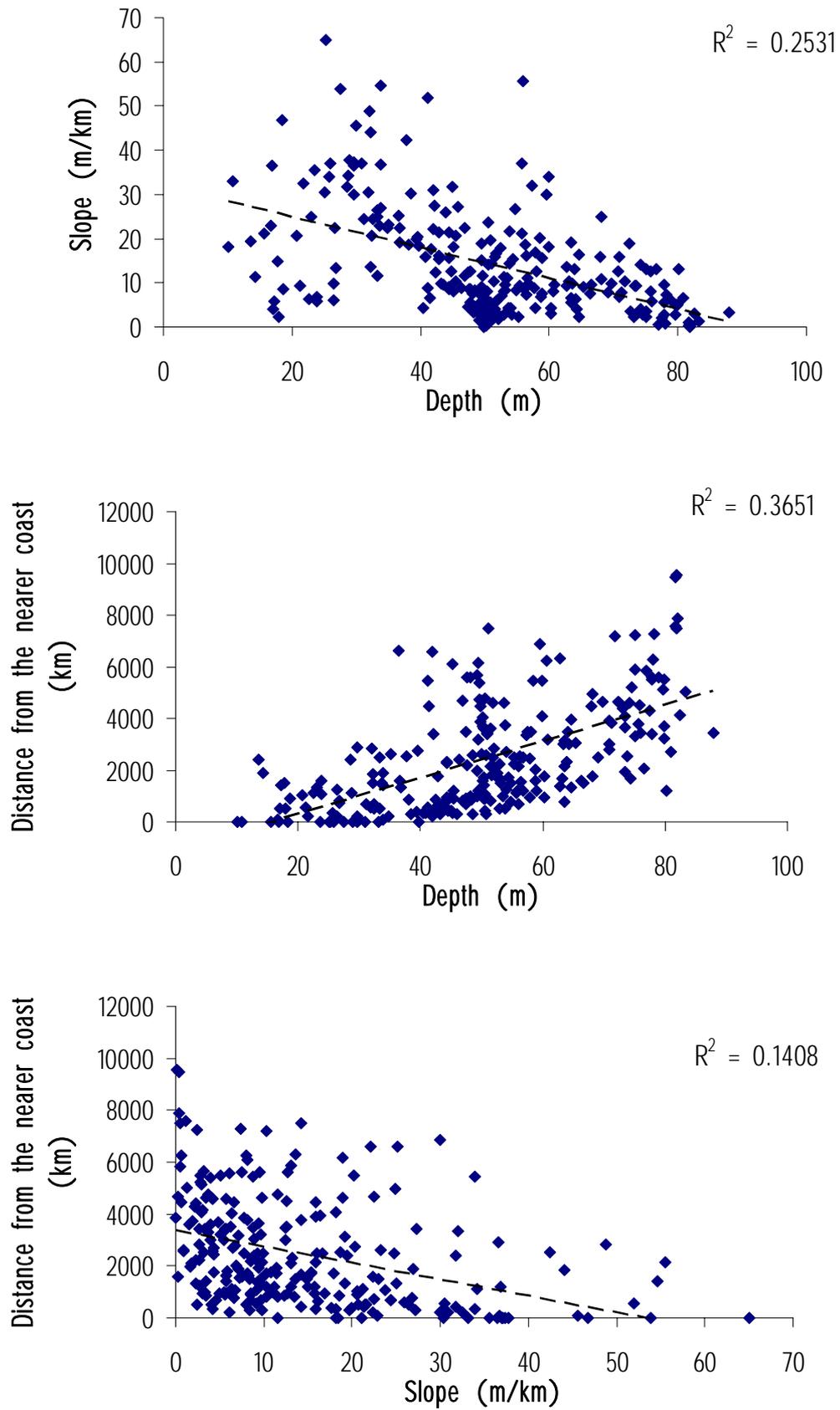


Figure 3.2 - Correlations between explanatory variables: depth (m), distance from the nearer coast (DISTANCE, km), and slope (m/km)

The potential influence of temporal variation on the distribution of bottlenose dolphins was also investigated. The available data were sufficient to run the following GLMs: (a) one model on all pooled data; (b) two models to investigate seasonal changes: summer (21st June-21st September) and all other seasons; (c) two models to investigate daily changes (morning = 6:00-12:00 and afternoon = 12:01-18:00); (d) three models to investigate inter-annual changes (triennium 1 = 1995-1997; triennium 2 = 1998-2000; and triennium 3 = 2001-2003).

3.2.3.6 Correlations between the number of recreational boats and the explanatory variables

GLMs were run on the data for each year to investigate the relationships between the increase/decrease in the number of boats within the archipelago and explanatory covariates included in the models. A correlation test for binary data was used to determine the strength of any relationship.

3.3 RESULTS

3.3.1 Dolphin surveys

Between 1995 and 2003, a total of 681 surveys were carried out, covering 32,457 km. Over 92% of the effort was conducted in good survey conditions (Beaufort <3 and good visibility) with 339 encounters of bottlenose dolphins recorded (Table 3.1).

Table 3.1 – Summary of the research effort

Year	Research season	Total surveys	Total effort (km)	Total effort in good conditions (km)	Total no. encounters	Total no. encounters in good conditions	ER ₁ (effort ≥ 1.414 km only)	ER ₂ (effort ≥ 1.414 km only)
1995	April - October	96	4,757	3,631	56	50	0.018	0.013
1996	May – October	81	4,727	3,449	34	31	0.010	0.008
1997	May – October	97	4,528	3,110	61	51	0.019	0.015
1998	February – September	80	3,599	2,315	46	39	0.019	0.016
1999	June – October	50	2,001	1,506	30	25	0.022	0.017
2000	April – September*	56	2,933	1,855	41	31	0.017	0.018
2001	June – October	67	3,606	2,859	37	30	0.013	0.010
2002	May – October	71	2,652	2,808	34	28	0.009	0.008
2003	May – October	83	3,654	3,379	62	54	0.020	0.016
95-03	54 months with effort	681	32,457	24,912	401	339	0.016 (0.002)	0.013 (0.001)

Key: ER₁ is the annual mean of cell encounter rates in good survey conditions; ER₂ is the total number of encounters divided by the total number of km surveyed each year. Standard errors in brackets.

* *May excluded.*

Seventy percent of the data were collected during the summer season. Analyses presented here refer only to the portion of the study area overlapped by the selected grids (GRID1 and GRID4); resulting in a loss of 2% of the total data.

Limiting the calculation of ER₁ and ER₂ to all cells with annual effort ≥ 1.414 km, 10% and 14% of effort and encounters, respectively, were discarded.

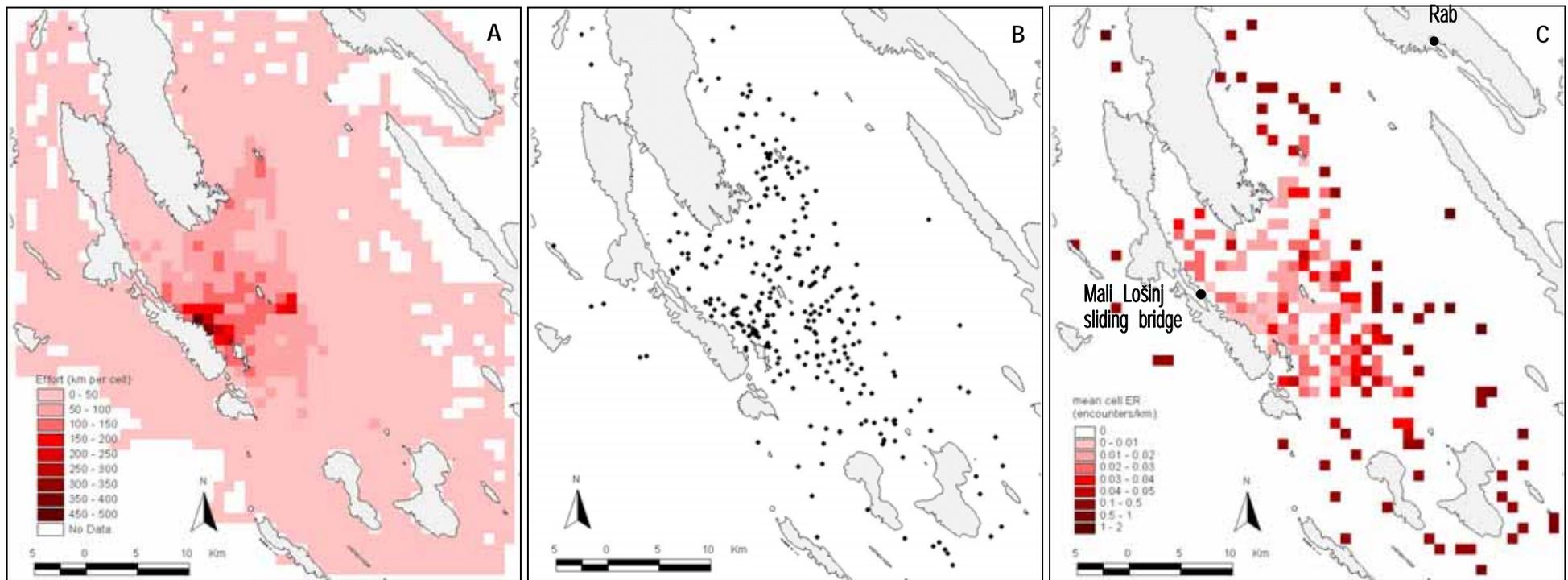


Figure 3.3 – Graphical summary of all data (1995-2003) plotted for 1 km² grid cells. A. Total survey effort, B. all encounters, and C. mean encounter rate (total number of encounters/total number of km) per cell

Effort was clearly more intensive in the core area and influenced by the starting harbours (Fig. 3.3A) on the island of Lošinj. Of the 1,566 cells of GRID1, dolphin encounters were recorded in only 13 % (N=201). Within the most surveyed portion of the study area, encounters were widely spread (Fig 3.3A and 3.3B), except for an area between the Mali Lošinj sliding bridge and Rab harbour that showed a null encounter rate (Fig 3.3B and 3.3C). Figure 3.3C also appears to show a higher encounter rate at the northwest border of the surveyed area (Fig 3.3C). However, a map of encounter rate at a scale of 64 km² shows that this is primarily a result of the high variability in encounter rate for cells where there was low effort (Fig. 3.4).

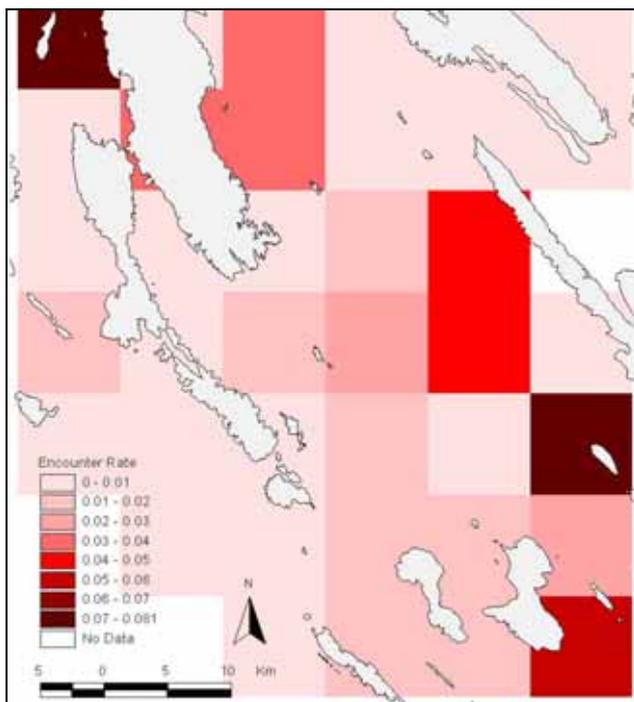


Figure 3.4 – Mean cell encounter rate for 64km² grid cells (total number of encounters/ total number of km surveyed in each cell)

The overall mean encounter rate ER₁ (encounters/km surveyed in each cell) for cells with annual effort ≥ 1.414 km in the Kvarneric was 0.016 (N=902; SE=0.002;

range=0.000-0.644). The mean group size was 6.2 (N=339; SD=6.0; SE=0.3; range=1-45; median=4.0). The annual encounter rate was quite variable but did not show any clear trend over time (Fig. 3.5).

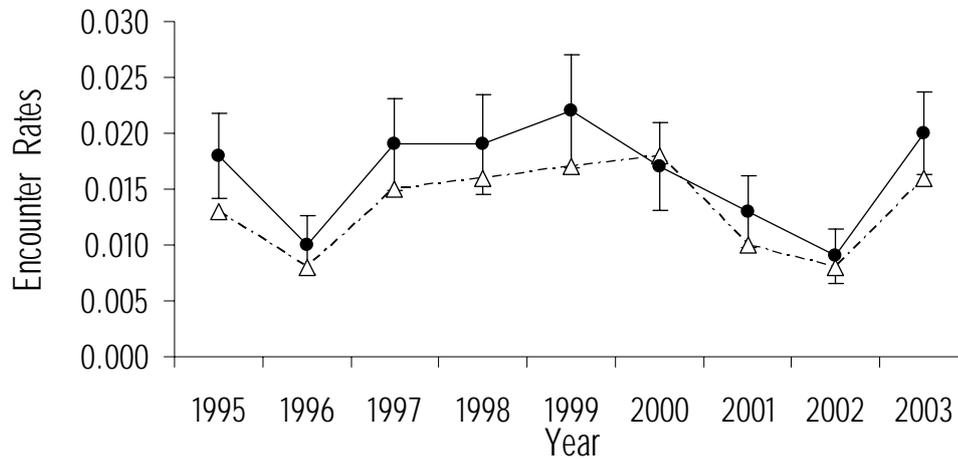


Figure 3.5 - Annual mean cell Encounter Rates, ER₁ (encounters/km per cell; solid circles and line); Annual Encounter Rate, ER₂ (total encounters/total km; open triangles and dashed line)

Descriptive statistics of each explanatory variable per cell based on effort (N=41,225 that is the total number of times cells were crossed) and related to the encounters are given in Tables 3.2 and 3.3, respectively.

Table 3.2 - Descriptive statistics of variables in all 1 km² grid cells where there was survey effort

Variable	Mean	Median	SD	SE	CI 95%	Range
DEPTH (m)	47.8	49.7	21.3	0.5	46.7 - 48.9	0.3 - 88.8
SLOPE (m/km)	14.7	10.5	14.7	0.4	13.4 - 15.4	0.0 - 116.8
DIST.COAST (km)	2.3	1.7	2.2	0.1	2.2 - 2.5	1.0 - 9.9
MAN.FIX (km)	12.1	11.7	6.1	0.2	11.8 - 12.4	1.0 - 29.2
lnMAN.MOV (km)	9.1	9.4	1.7	0.0	9.0 - 9.1	0 - 10.6
TRAWL (Y/N)	In 58 % of the cases the effort was made in trawling areas					

Table 3.3 - Descriptive statistics of variables in 1 km² grid cells where there were encounters with dolphins (N = 339)

Variable	Mean	Median	SD	SE	CI 95%	Range
DEPTH (m)	49.7	50.0	17.1	0.9	47.9 - 51.5	10.1 - 87.9
SLOPE (m/km)	14.5	10.3	12.3	0.7	13.2 – 15.9	0.02 - 65.1
DIST.COAST (km)	2.5	1.9	2.0	0.1	2.2 – 2.7	1.0 – 9.5
MAN.FIX (km)	10.5	10.3	5.7	0.30	9.9– 11.1	1.0 – 27.8
LnMAN.MOV (km)	8.6	9.0	2.0	0.1	8.4-8.8	0.0 - 10.6
TRAWL (Y/N)	In 66% of the cases encounters were made in trawling areas					

3.3.2 Anthropogenic factors - Trawlers

A total of 526 working trawlers were inspected to check for the presence of bottlenose dolphins in their vicinity. Dolphins were found in 10% of cases. The encounters behind the trawlers in good survey conditions were 13% of the overall encounters (44 out of 339). Table 3.4 shows a detailed summary of data collected.

Table 3.4 – Encounters behind working bottom trawlers

Year	Good conditions		Poor conditions		% of the total no. encounters in good conditions
	Trawlers checked	Encounters	Trawlers checked	Encounters	
1995	64	10	9	2	20
1996	40	3	18	0	10
1997	32	3	14	0	6
1998	24	2	17	2	5
1999	39	5	11	1	20
2000	28	4	29	3	13
2001	47	2	14	0	6
2002	56	6	25	3	21
2003	54	9	5	0	17

The index of trawler exploitation (in good survey conditions) did not show any particular trend, although there appears to be an increase in variability after 1998 (Fig. 3.6).

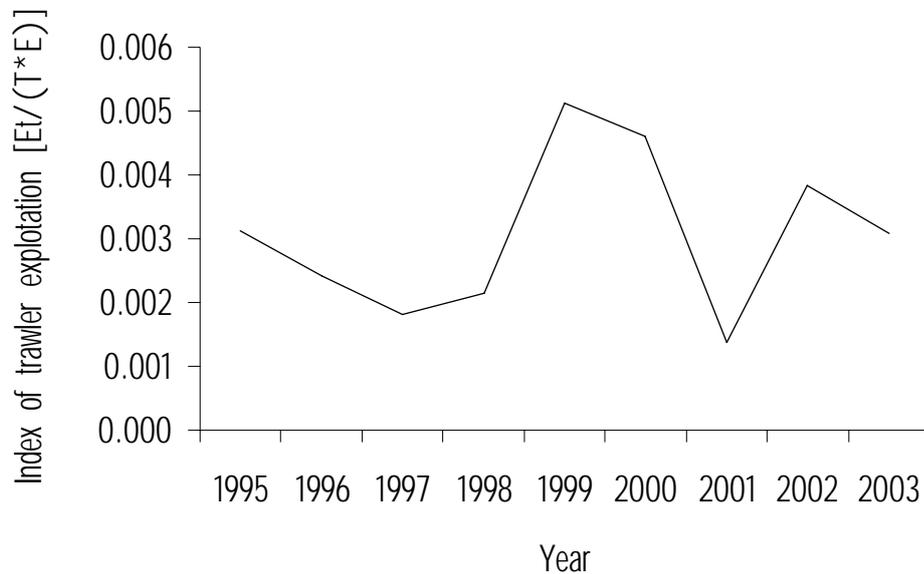


Figure 3.6 – Index of “exploitation” for bottlenose dolphin observed around trawlers

3.3.3 Anthropogenic factors - Tourism

Information received from the harbour master’s office in Mali Lošinj, highlights the growth of boating in the region (Table 3.5A). In 2003 the number of domestic and foreign registered boats increased by 900 vessels (Tomić, Mali Lošinj Harbour Master, personal communication). In addition to these users, a considerable number of foreign and domestic boats use the harbour of Mali Lošinj for different purposes, such as: refuelling, fish selling, crew replacement and small repairs. These boats do not have an obligation to report their presence to the local authority. The office of the Mali Lošinj harbour master estimates that, during the peak tourist season, such unregistered boats

increase the daily traffic within the archipelago by about 30-50% (Mali Lošinj Harbour Master Official Statistics Report 2004).

Table 3.5 – Available data on tourist fluxes in the archipelago: number of registered boats (A), tourist nights (B); NA = not available

Year	A			B			
	Foreign boats registered at the Harbour Master offices			No. of nights spent by tourists in the archipelago			
	Mali Lošinj	Rab	Total	Lošinj island	Rab island	Pag island	Total
1990	4276	1056	5332	2,047,025	1,680,500	931,006	4,658,531
1991	1462	2139	3601	356,418	173,000	NA	> 529,418
1992	NA	NA	NA	497,000	189,738	4,779	691,517
1993	3241	2139	5380	750,000	432,278	6,616	1,188,894
1994	3646	3225	6871	1,315,362	770,586	79,311	2,165,259
1995	2190	2324	4514	947,827	394,616	86,176	1,428,619
1996	3654	3688	7342	1,421,717	874,008	125,073	2,420,798
1997	3402	4134	7536	1,587,900	1,170,686	207,001	2,965,587
1998	3634	4291	7925	1,601,578	1,200,085	235,769	3,037,432
1999	3301	4035	7336	1,400,930	969,068	205,927	2,575,925
2000	3648	4713	8361	1,722,400	1,390,810	343,835	3,457,045
2001	3644	4735	8379	1,851,298	1,490,855	449,945	3,792,098
2002	3696	4922	8618	1,844,983	1,444,845	475,022	3,764,850

The area hosts about 24,000 permanent residents; however, during the high season the population may increase by 20 times. The impact of the Balkans conflict on this region is clearly evident. Tourism dropped to a minimum in 1991 when the Croatian War of Independence (1991-1995) started and all foreigners were asked to leave the country (Table 3.5B). Hostilities officially ended in December 1995 (Dayton peace agreement), however life on the Cres-Lošinj archipelago had already started to return to normal in 1994 with tourists returning. Nevertheless, to date, the number of tourists has not yet reached the level experienced before the war in ex-Yugoslavia.

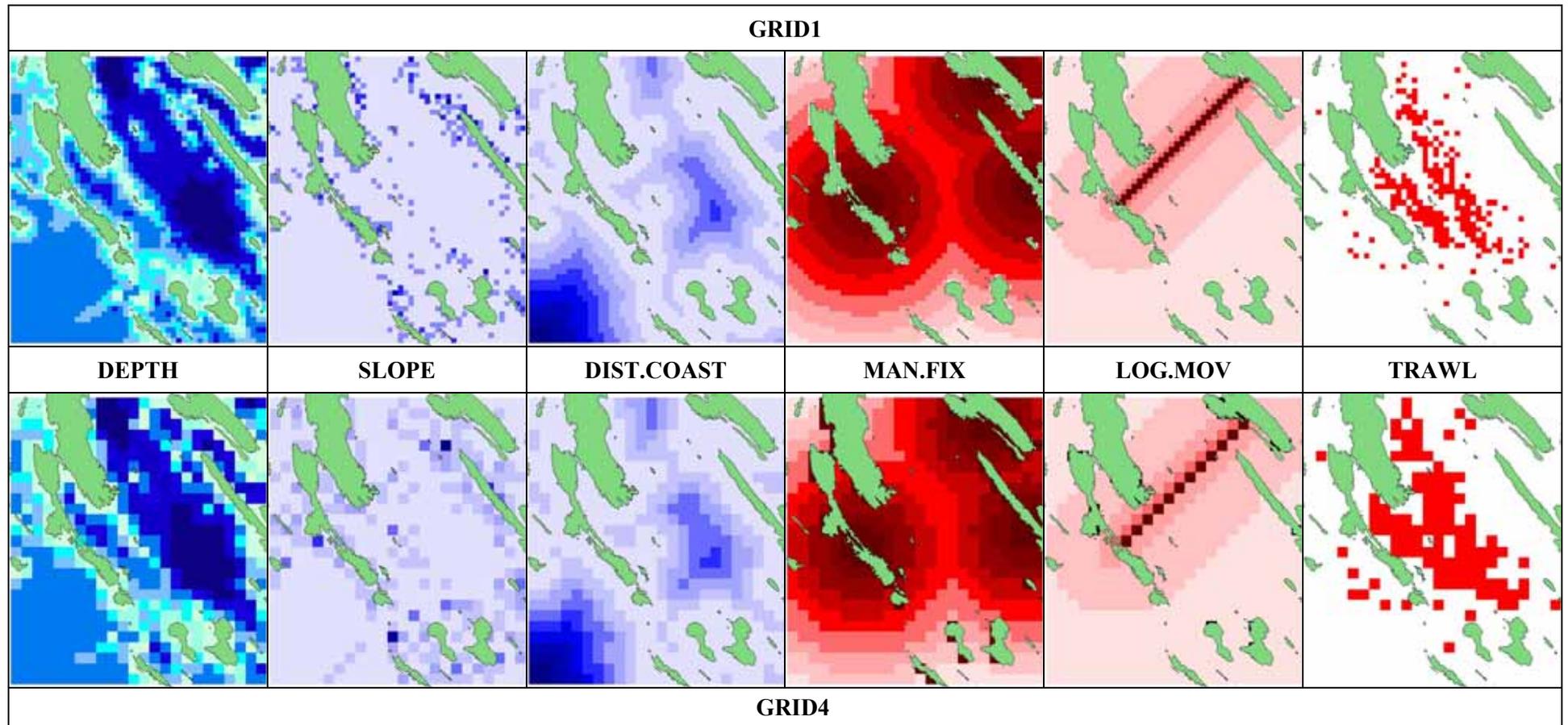


Figure 3.7 – Spatial variation in the main explanatory variables over the study area at two scales (GRID1 = 1 km², GRID4 = 4 km²)

3.3.4 Habitat usage

Maps of the explanatory variables used in the GLMs, at the two different spatial scales, are shown in Figure 3.7.

3.3.4.1 GLM fits (GRID 1)

3.3.4.1.1 Overall model

Fifty percent (n=51) of habitat categories (see section 3.2.3.4) included in the GLM (n=101) were used by dolphins.

Table 3.6 – Results of GLM analysis of probability of encountering bottlenose dolphins using the complete dataset, including variable and intercept estimates and level of significance. MAN.FIX= distance from three marine petrol stations; lnMAN.MOV= natural logarithm of the distance from the route connecting the two main harbours; TRAWL=trawling areas – (GRID1)

Covariate	Estimate	Probability
DEPTH	1.786×10^{-2}	$p < 0.05$
DEPTH ³	-1.583×10^{-6}	$p > 0.05$
MAN.FIX	5.091×10^{-5}	$p < 0.001$
ln.MAN.MOV	6.130×10^{-2}	$p > 0.05$ ($p = 0.062$)
TRAWL	0.471	$p < 0.001$
<i>Intercept</i>	<i>-6.671</i>	<i>p < 0.001</i>

The only natural variable that played an important role for the distribution of dolphins was DEPTH and it had a positive effect on dolphin presence (Table 3.6). All other factors that had an impact on the presence/absence of dolphins were anthropogenic. Among these, proximity to marine petrol stations (MAN.FIX) had a negative impact on the presence of dolphins, while the presence of trawlers (TRAWL) had a positive

impact. The distance from the main “marine highway” (lnMAN.MOV) and the cubic term of DEPTH were also included in the final model, increasing the variability explained, but their influence was not significant. Note that the coefficients for MAN.FIX and lnMAN.MOV were positive, indicating that an increase in distance from areas with a high level of anthropogenic use corresponded to an increase in encounter probability.

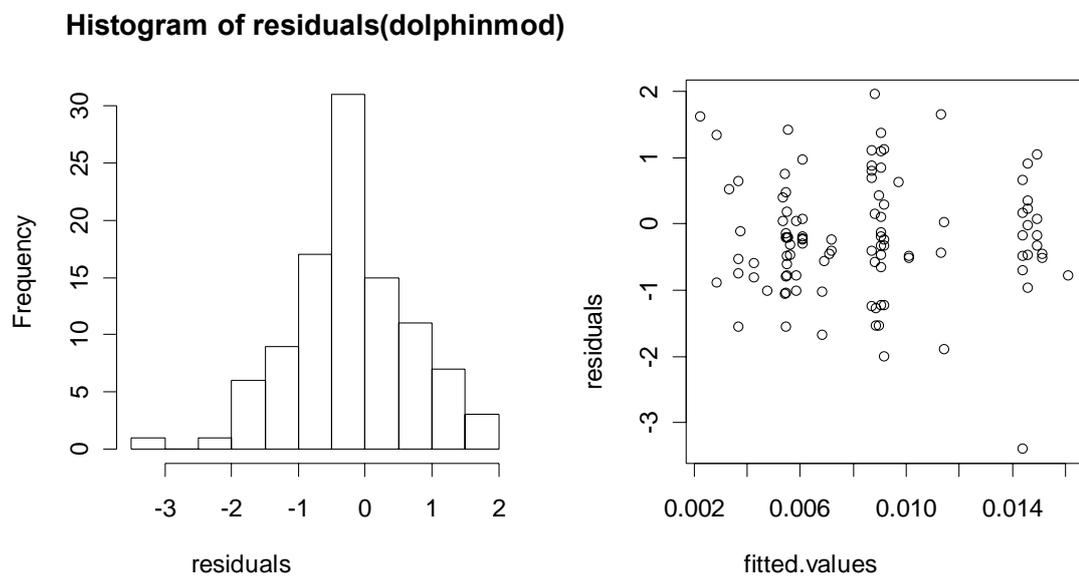


Figure 3.8 - Plot of residuals for the overall GLM documented in Table 3.6

The distribution of the residuals (Fig. 3.8) and the high explained variability (44%) give an indication of the model reliability. As expected from the measures of model reliability, there was a high concordance between the GLM prediction of presence (Fig. 3.9) and the relative density of encounters (Fig. 3.3).

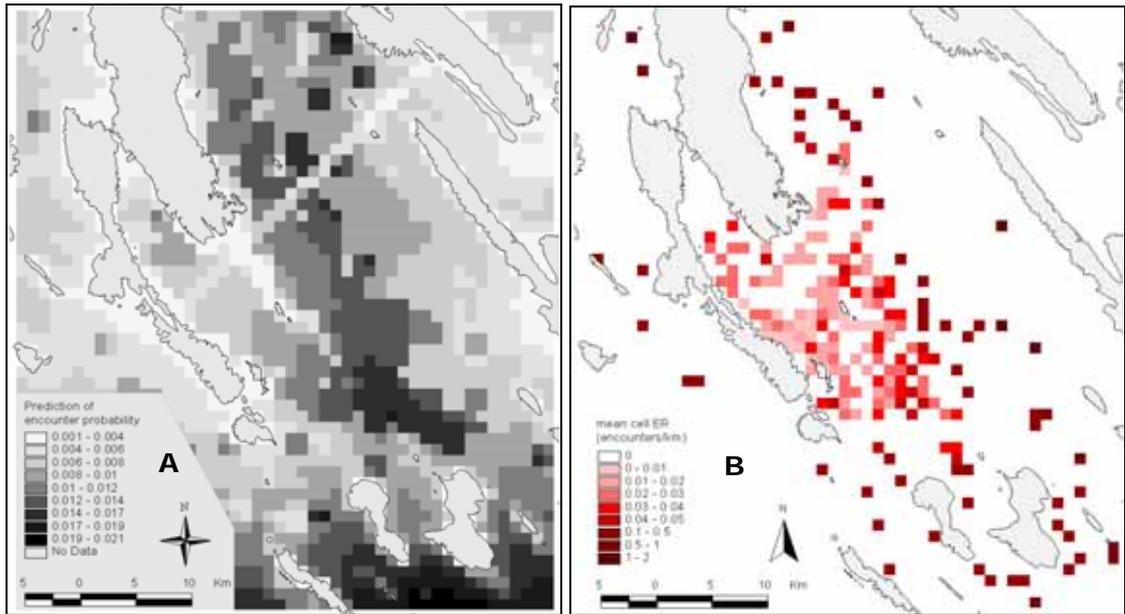


Figure 3.9 – A. Prediction of encounter probability for the complete dataset B. observed mean encounter rate (B) (total number of encounters/total number of km surveyed per cell)

3.3.4.1.2 Seasonal models

The results of the “summer model” were very similar to the “overall” model, characterised by the presence of the same significant variables, with the addition of the cubic term of DEPTH and lnMAN.MOV, both of which had a significant negative effect. This model also had a high explained variability (45%).

In the analysis of the “all other seasons” dataset (33% of the overall dataset) the only factors affecting dolphin distribution were MAN.FIX (negatively related) and trawling areas (positively related). The variability explained by this model was only 17%. Details are given in Table 3.7.

Table 3.7 – Results of GLM analysis on seasonal datasets, including variable and intercept estimates and level of significance. DIST=distance from the nearer coast; MAN.FIX= distance from three marine petrol stations; lnMAN.MOV=natural logarithm of the distance from the route connecting the two main harbours; TRAWL=trawling areas – (GRID1)

Summer		
Covariate	GLM Estimate	Probability
DEPTH	2.404×10^{-2}	$p < 0.05$
DEPTH ³	-2.242×10^{-6}	$p > 0.05$ ($p = 0.051$)
MAN.FIX	5.431×10^{-5}	$p < 0.001$
ln.MAN.MOV	-0.092	$p < 0.05$
TRAWL	0.413	$p < 0.01$
<i>Intercept</i>	<i>-7.120</i>	<i>p < 0.001</i>
Other seasons		
Covariate	GLM Estimate	Probability
MAN.FIX	4.527×10^{-5}	$p < 0.01$
TRAWL	0.683	$p < 0.01$
<i>Intercept</i>	<i>-5.662</i>	<i>p < 0.001</i>

Graphs of residuals for these two models are given in Annex 1.

The maps of predicted distribution (Fig. 3.10) show clearly the magnitude of the impact of the lnMAN.MOV covariate on dolphin distribution in summer.

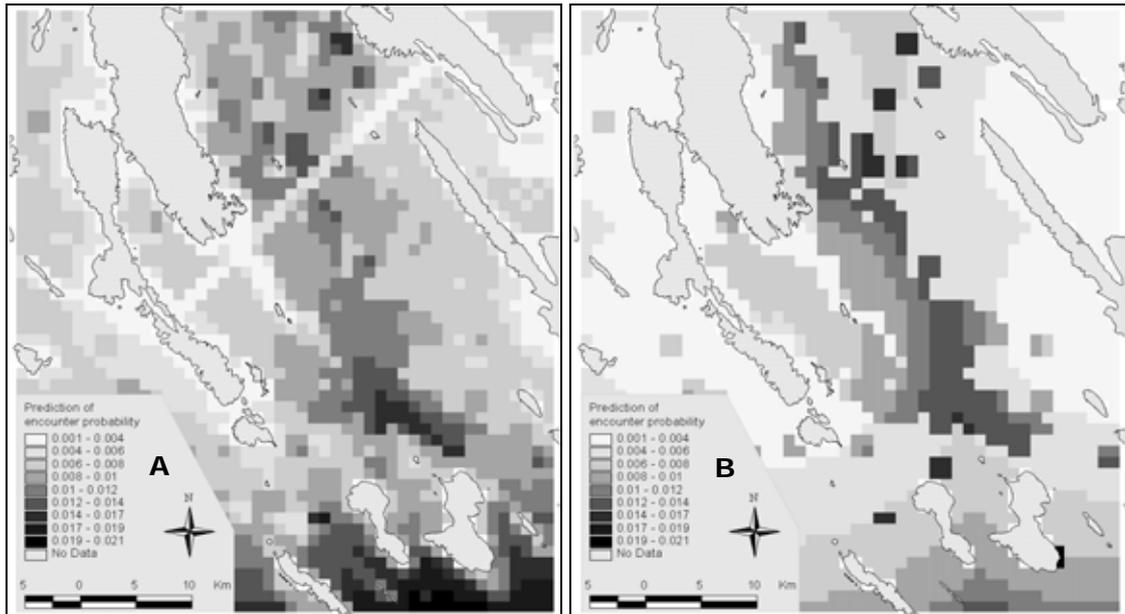


Figure 3.10 - Predictions of seasonal encounter probability for dolphin. A, summer; B, all other seasons

3.3.4.1.3 Diurnal models

The “morning” model (32% of the overall dataset) was similar to the “other seasons” model due to the inclusion of $\ln.MAN.MOV$, but this covariate was not statistically significant (Table 3.8). The “afternoon” model was characterised by the combination of two covariates exerting a negative effect ($MAN.FIX$ and $DEPTH^3$), and two exerting a positive effect ($DEPTH$ and $TRAWL$) (Table 3.8). The explained variability was similar in both subsets (35 and 36%, between 06:00 and 12:00 and between 12:01 and 18:00, respectively). Graphs of residuals for these two models are given in Annex 1. The predictive maps show the absence of bottlenose dolphin groups in the morning from the route between Lošinj and Rab, whilst in the afternoon this was not the case (Fig. 3.11).

Table 3.8 – Results of GLM analysis of morning and afternoon datasets, including variable and intercept estimates and level of significance. DIST=distance from the nearer coast; MAN.FIX= distance from three marine petrol stations; lnMAN.MOV=natural logarithm of the distance from the route connecting the two main harbours; TRAWL=trawling areas – (GRID1)

Morning		
Covariate	GLM Estimate	Probability
MAN.FIX	7.252×10^{-5}	$p < 0.001$
ln.MAN.MOV	0.1217	$p > 0.05$ ($p = 0.081$)
TRAWL	0.657	$p < 0.01$
<i>Intercept</i>	-6.792	$p < 0.001$
Afternoon		
Covariate	GLM Estimate	Probability
DEPTH	2.879×10^{-2}	$p < 0.001$
DEPTH ³	-2.901×10^{-6}	$p < 0.05$
MAN.FIX	4.666×10^{-5}	$p < 0.001$
TRAWL	0.507	$p < 0.01$
<i>Intercept</i>	-6.492	$p < 0.001$

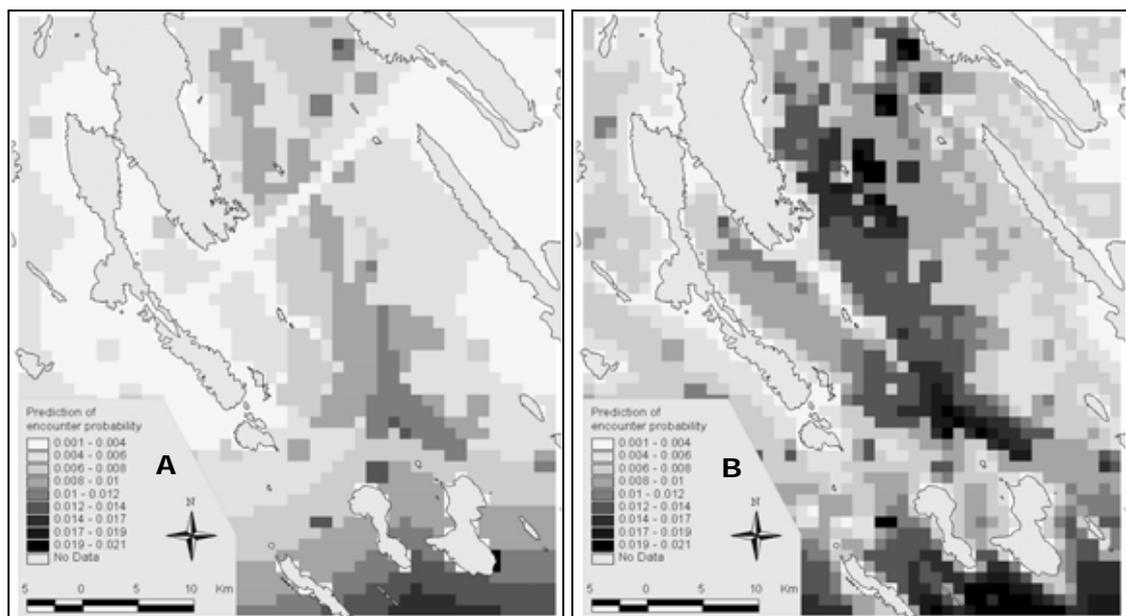


Figure 3.11 - Predictions of dolphin encounter probability on a diurnal basis: A, morning; B, afternoon

3.3.4.1.4 Triennial models

There was a clear change over the three triennial periods in the explanatory covariates that affected the presence of bottlenose dolphins (Table 3.9, Fig. 3.12).

Table 3.9 – Results of GLM analysis of triennial datasets, including variable and intercept estimates and level of significance. DIST=distance from the nearer coast; SLOPE:DIST=interaction term for slope and DIST; MAN.FIX= distance from three marine petrol stations; lnMAN.MOV=natural logarithm of the distance from the route connecting the two main harbours; TRAWL=trawling areas – (GRID1)

1995-1997		
Covariate	GLM Estimate	Probability
DEPTH	1.006×10^{-2}	$p < 0.05$
MAN.FIX	7.410×10^{-5}	$p < 0.001$
<i>Intercept</i>	-5.882	$p < 0.001$
1998-2000		
Covariate	GLM Estimate	Probability
SLOPE	0.223	$p > 0.05$
DIST	4.171×10^{-3}	$p > 0.05$
SLOPE:DIST	-2.041×10^{-4}	$p > 0.05$
TRAWL	0.535	$p < 0.05$
<i>Intercept</i>	-9.449	$p > 0.05$
2001-2003		
Covariate	GLM Estimate	Probability
DEPTH	4.814×10^{-2}	$p < 0.01$
DEPTH ³	-5.948×10^{-6}	$p < 0.001$
MAN.FIX	6.353×10^{-5}	$p < 0.001$
ln.MAN.MOV	0.200	$p < 0.05$
TRAWL	0.779	$p < 0.001$
<i>Intercept</i>	-9.298	$p < 0.001$

Of particular importance were the changes in the second triennium (Table 3.9, Fig. 3.12). During this period the presence of dolphins was significantly related only to trawling areas; two additional non-significant physical factors were retained in the model (SLOPE and DIST). This model explained 15% of the variability. In contrast, during the first and last triennia the anthropogenic variables had the greatest influence on dolphin presence. During the first triennial period, the trawling areas were not included in the model, which explained 35% of the variability. Only in the final period (2001-2003) was the variable $\ln\text{MAN.MOV}$ significant ($p < 0.05$), when the model explained 48% of the variability. Graphs of residuals for these three models are given in Annex 1.

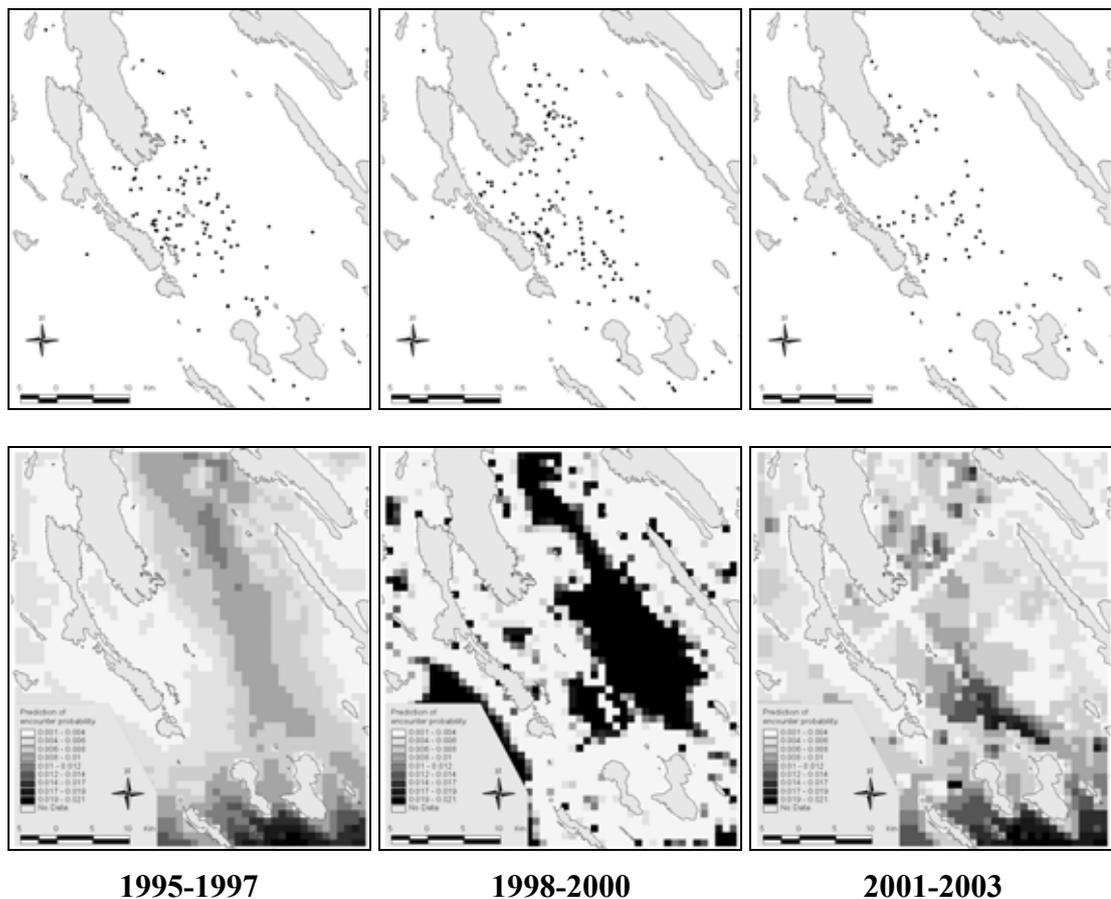


Figure 3.12 – Distribution of encounters and predictions of dolphin encounter probability for the three triennial periods

Within the boundaries of the proposed MPA we selected, combining all the predictive maps, cells were selected in which the overall encounter probability of bottlenose dolphins was two to four times higher than in the remaining cells. Around these cells a buffer of 500 m radius was created (Fig. 3.13A – in blue) to highlight areas that were used more often by bottlenose dolphins. Similarly, cells where the encounter probability was half that of other cells were selected and a buffer of 500 m radius created around them (Fig. 3.13B – in red). These buffer zones therefore represent areas of relatively high use and relatively low use, respectively. Because results from different stratifications of the data have been used to create the buffer zones, there are overlaps between the high use and low use areas. These overlap areas may be of particular importance for dolphins (Fig. 3.13A – dashed black oval).

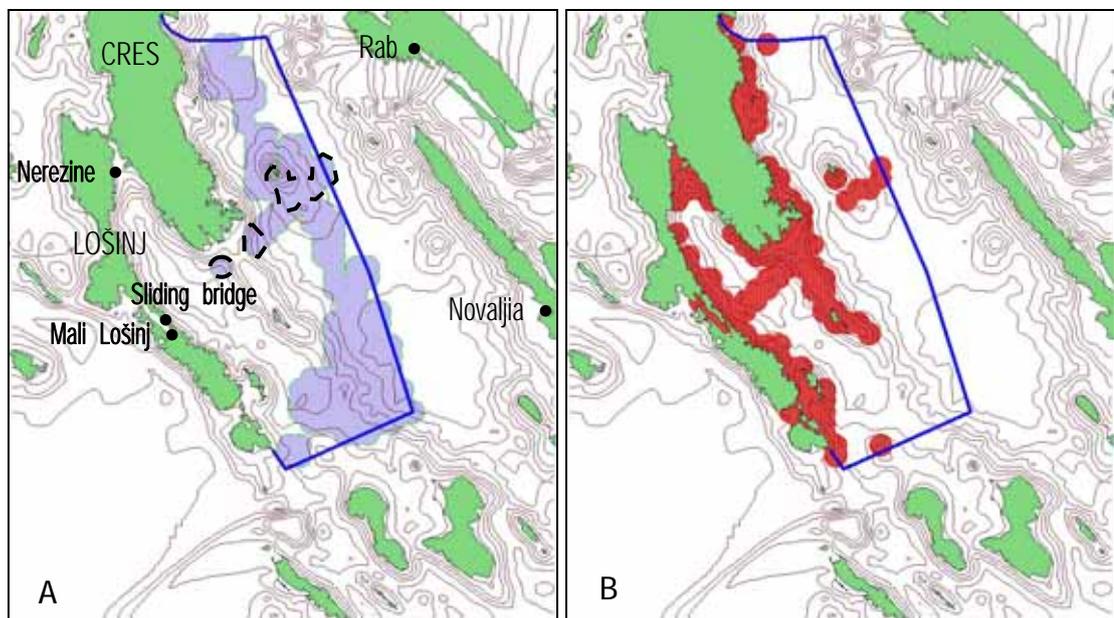


Figure 3.13 - Areas predicted to be used most frequently (A) or used least frequently (B) for local bottlenose dolphins within the boundaries of the proposed MPA. Buffers within the dashed irregular shapes (A) represent potential areas of particular importance

3.3.4.1.5 Relationship between the number of recreational boats and the explanatory variables

Results from the GLM analyses of annual datasets are given in Table 3.10. The models for 2001 and 2003 had a relatively high explained variability (53% and 36% respectively); all the others had between 10 and 28% of the variance explained.

Nevertheless, all explanatory variables kept in each annual model were tested for their potential correlation with the annual increase in the number of boats registered, in both the preceding and same year when such an increase was recorded (Table 3.11). In fact, a backward stepwise GLM model builds a model by eliminating different variables which do not improve the fit by a significant amount. Thus all explanatory variables present in the final model, even when not statistically significant, must be considered important.

Only two high correlations were found: one with the distance from the main marine petrol stations and harbours (Simple matching binary similarity coefficients = 0.67), one year after an increase occurred; and the other with the trawling areas (Simple matching binary similarity coefficients = 0.67) during the same year that an increase occurred.

Table 3.10 – Results of GLM analysis on annual datasets, including variable estimates and level of significance. Shaded cells highlight significant explanatory variables. DIST=distance from the nearer coast; DEPTH:SLOPE=interaction term between depth and slope; MAN.FIX= distance from three marine petrol stations; lnMAN.MOV=natural logarithm of the distance from the route connecting the two main harbours; TRAWL=trawling areas – (GRID1)

Year	DEPTH	DEPTH ³	SLOPE	DIST	DEPTH: SLOPE	MAN. FIX	ln.MAN. MOV	TRAWL
1995	2.864 x 10 ⁻¹ p>0.05		2.160 x 10 ⁻¹ p>0.05		-1.371 x 10 ⁻² p>0.05	5.232 x 10 ⁻⁴ p>0.05		
1996	0.023 p<0.05							
1997				1.481 x 10 ⁻⁴ p>0.05		8.391 x 10 ⁻⁵ p<0.001		
1998						6.073 x 10 ⁻⁵ p<0.05		8.123 x 10 ⁻¹ p<0.05
1999	0.0232 p<0.05						4.319 p>0.05	
2000				0.0003 p>0.05				
2001	8.143 x 10 ⁻² p<0.05	-9.193 x 10 ⁻⁶ p<0.05	-4.237 x 10 ⁻¹ p>0.05			1.070 x 10 ⁻⁴ p<0.001	2.779 x 10 ⁻¹ p>0.05	
2002			3.011 x 10 ⁻² p<0.05			5.841 x 10 ⁻⁵ p>0.05	4.282 p>0.05	9.403 x 10 ⁻¹ p<0.05
2003	4.77 x 10 ⁻⁴ p<0.05	-6.482 x 10 ⁻⁶ p<0.05				5.014 x 10 ⁻⁵ p<0.05		9.626 x 10 ⁻¹ p<0.05

Table 3.11 – Correlation table between increase or decrease of the number of registered boats and all explanatory variables. Key: ↑= increase, ↓= decrease, 1=variable present in the model, 0=variable not present in the model, D=depth, S=slope, DS=distance from the nearer coast; D:S=interaction term between depth and slope; MF= distance from three marine petrol stations; MM=distance from the route connecting the two main harbours; T=trawling areas

Year	Boats previous year	D	D ³	S	DS	D:S	MF	ln MM	T
1995	↑	1	0	1	0	1	1	0	0
1996	↓	1	0	0	0	0	0	0	0
1997	↑	0	0	0	1	0	1	0	0
1998	↓	0	0	0	0	0	1	0	1
1999	↑	1	0	0	0	0	0	0	0
2000	↑	0	0	0	1	0	0	0	0
2001	↑	1	-1	1	0	0	1	1	0
2002	↑	0	0	1	0	0	1	1	1
2003	↑	1	-1	0	0	0	1	0	1

3.3.4.2 GLM fits (GRID 2000)

3.3.4.2.1 Overall model

Results from the “overall” model run on the GRID4 dataset were very similar to those obtained for the GRID1 dataset (Table 3.12), except for the absence of the covariate lnMAN.MOV. In addition, this model explained less variability (41%) compared to the one obtained using the GRID1 dataset. Some differences were noted within the seasonal and triennial models. Complete results are presented in Annex 1.

Table 3.12 – Results of GLM analysis on the complete dataset, including variable and intercept estimates and level of significance. MAN.FIX= distance from three marine petrol stations; lnMAN.MOV=natural logarithm of the distance from the route connecting the two main harbours; TRAWL=trawling areas – (GRID4)

Covariate	GLM Estimate	Probability
DEPTH	1.184×10^{-2}	$P < 0.001$
SLOPE	-1.046×10^{-2}	$p > 0.05$
MAN.FIX	4.456×10^{-5}	$P < 0.001$
TRAWL	0.420	$P < 0.01$
<i>Intercept</i>	<i>-5.697</i>	<i>p < 0.001</i>

The predictive map (Fig. 3.14), based on the GLM results, showed a similar pattern to the GRID1 one; however, the absence of the effect of the lnMAN.MOV covariate is clear.

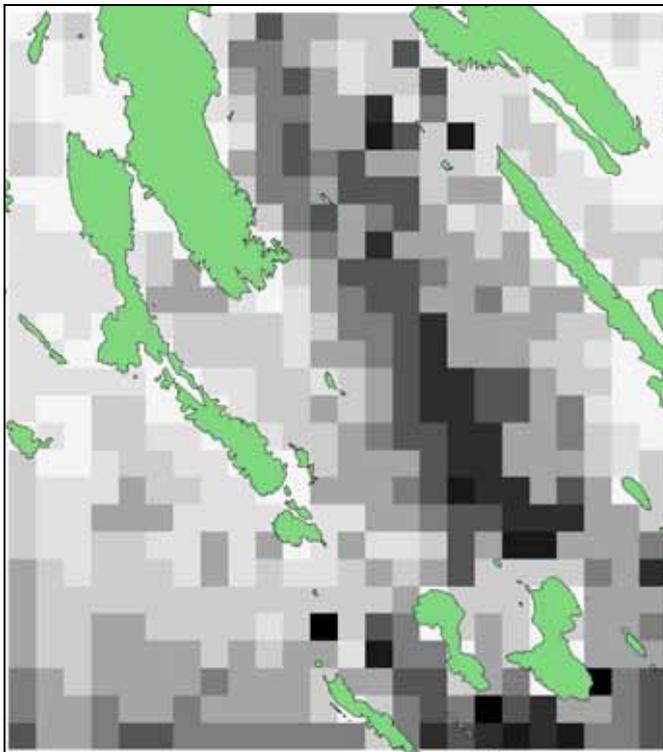


Figure 3.14 - Predictive map of the overall data (GRID4)

3.4 DISCUSSION

3.4.1 Significance for bottlenose dolphins of anthropogenic activities

Results from the overall model show that bottlenose dolphin presence was negatively affected by two out of three anthropogenic covariates. One was the distance from the three harbours with marine petrol stations facilities, which can be considered as a proxy for effects related to the physical presence of boats. The other was a function of the distance from the main route connecting two of the primary harbours of the archipelago, which corresponds to the presence of fast moving vessels (Rako 2006). The latter had a more spatially and temporally localised effect (Fig. 3.10, 3.11 and 3.12). Both parameters are associated with various types of boat traffic noise, mostly low frequency but very high intensity sounds (Rako 2006). Reactions to noisy and fast moving objects have previously been demonstrated for different species of cetacean. The most common avoidance reaction, especially to boats manoeuvring unpredictably, was an increase in inter-breath intervals by carrying out longer dives (Evans *et al.* 1992, Janik and Thompson 1996, Novacek *et al.* 2001, Hastie *et al.* 2003a). Other reported reactions include short-term changes in swimming speed and direction (Novacek *et al.* 2001), behavioural disruption and changes in habitat use (Allen and Read 2000, Hastie *et al.* 2003a, Lusseau 2003a and 2003b, Sini *et al.* 2005). Frid and Dill (2002) proposed that fast moving objects are perceived by animals as predators and their reaction can be treated as an anti-predator behaviour. If this occurred in this area, the increase in diving times would have reduced the probability of their being hit by boaters, but also the probability of being spotted by our observers. This latter effect could explain the absence of encounters with dolphins on the route between Lošinj and Rab. Alternatively, dolphins may simply be avoiding this specific area during certain periods of the day.

Stratifying the data by time helped to clarify the impact of particular factors. Results clearly showed that in the morning the primary route used by speed boats was the area least used by bottlenose dolphins. In the afternoon, when many tourists have crossed the archipelago and are anchored in small bays, such avoidance did not occur (Fig 3.11). In addition, an overall avoidance effect along the coasts of Lošinj and Cres island was also detected, regardless of the time of the day.

Every day at 9:00am the sliding bridge in Mali Lošinj is opened to allow the passage of large vessels and sailing boats (height of the upper deck or mast more than 2 m, on the sea level). The Mali Lošinj sliding bridge is one of the two northernmost gates for the Italian, Slovenian and Istrian boaters for the entire Croatian archipelago.

According to the report given by the Harbour Master of Mali Lošinj, between 30-50% of those passing through are not staying within the Kvarnerić archipelago, but refuelling in Mali Lošinj and heading south to the Kornati National Park (Harbour Master Zoran Tomić, pers. comm.).

The effect of temporal exclusion of dolphins caused by the boats using the route connecting Lošinj to Rab is confirmed by the outputs of seasonal models, where the light-grey stripe in the Summer Model indicates a lower probability of encountering a group of dolphins around that route at that time (Fig. 3.10).

With regards to the potential long-term effect on bottlenose dolphin habitat use by seasonal changes in numbers of speedboats, the results from analysing the data in triennial periods give cause for concern. The negative relationship between dolphin presence and distance from the main route connecting Lošinj to Rab only became significant during the last triennium. In addition to this, the distance from the three marine petrol stations became highly significant again after being non-significant during the second triennium. Thus it appears that during the last three years bottlenose

dolphins were most affected by activities along the route connecting Mali Lošinj and Rab harbours, and around the three main harbours and petrol stations. The correlation between the increase or decrease in the number of boats registered in the area in the previous year and the inclusion of the variable “distance from petrol stations” in the annual models, is further circumstantial evidence of the impact of the physical presence of boats, and very likely of the noise of their engines, as shown by Rako (2006). Moreover, the one-year time lag of the negative correlation between anthropogenic activities and presence of dolphins could imply a longer-term impact that could have implications for the welfare of the population. Further investigation on this particular aspect should be undertaken for future effective management of the area.

It is important to note that during the summer 2002 a new marine petrol station was built in Nerezine, in the core of the proposed MPA (Fig. 3.13). This location is indubitably convenient for boaters using the Cres-Lošinj archipelago; it allows them to refuel avoiding the long transit between the Mali Lošinj sliding bridge and the petrol station situated at the other end of Mali Lošinj harbour. Given the speed limit inside Mali Lošinj harbour the use of Nerezine’s facility enables boaters to refuel saving up to 40 minutes. The new marine petrol station has certainly increased the traffic in the core study area, especially around the south end of Cres island and therefore on the main route connecting Mali Lošinj and Rab islands.

3.4.2 Significance for bottlenose dolphins of natural variables and prey proxies

Bottom depth and trawling areas exerted a positive influence on the presence of bottlenose dolphins. Since these two factors may be directly related to prey distribution (see below), this result might be expected. Despite the fact that bottom trawling is detrimental for the benthic ecosystem, the link between the presence of

dolphins and trawlers could be due to two factors: a) the overlapping of fishing and feeding grounds and b) the exploitation by bottlenose dolphins of working bottom trawlers.

Although data on prey distribution and abundance within the Kvarnerić are scarce, there is evidence that bottom trawling areas correspond to areas with a higher density of hake (*Merluccius merluccius*) and other benthic fish (Adriamed 2001), as would be expected from the declared target species of this fishery. Such species are within the range of preferred prey of the Mediterranean bottlenose dolphin (Orsi Relini *et al.* 1994, Voliani and Volpi 1990), often being the main target (Blanco *et al.* 2001). The habit of bottlenose dolphins to follow working bottom trawlers has been well documented within this and other areas (Fertl and Leatherwood 1997, Fortuna *et al.* 1996, Bearzi and Nortarbartolo di Sciara 1997, Fortuna *et al.* 1998). Whether dolphins are stealing fish from the net or actively preying on other fish predators, attracted there by dead and disoriented prey, is unknown. It has been suggested, however, that such behaviour could represent a low energy foraging strategy, especially useful at certain stages of life (Fortuna *et al.* 1998). However, it could also be an indication of the reduced availability of fish resources within the Kvarnerić (Bearzi *et al.* 1999).

The strong positive relationship between the presence of dolphins and bottom depth also indicates that prey must play a fundamental role in dolphin distribution. This could be related to the biology of hake, which can be found in larger sizes in deeper waters (Vrgoč *et al.* 2004). If the “natural” explanatory variables (depth, slope, and distance from the nearest coast) are potential proxies for prey distribution, the lack of a high correlation between them and an increase in the number of boats seems to rule out any potential direct impact of tourism on prey distribution, except in the case of pelagic species.

The combination of an increase in the variability of the annual index of trawler exploitation after 1998 (Fig. 3.6) and the increased importance of the explanatory variable “trawling areas” with time (Table 3.9) could be a potential sign of some response to variations in the ecosystem related to prey. Information prepared by the Institute of Oceanography and Fisheries (Croatian Environmental Agency, http://baza.azo.hr/projekt_more/index.htm, first entered on 18 January 2005) clearly shows that, in the past five years, despite an increase in the size of the fleet and the average fishing power, there has not been an increase in total catch. The fishery statistics for the area that includes the Kvarnerić shows that most fish species have declined, especially *Mullus barbatus* and *Pagellus erythrinus*, whilst small pelagic blue fish species increased. Furthermore, according to local fishery interviews, the size of *Merluccius merluccius* has steadily decreased (Taylor 1998, Mackelworth 2006). All these species are regularly recorded in the diet of Mediterranean bottlenose dolphins (Orsi-Relini *et al.* 1994, Mikovic *et al.* 1999, Blanco *et al.* 2001). However, all this evidence is circumstantial, and rigorous scientific data on local fish stocks is required before any definitive conclusion can be drawn.

3.4.3 Potential implications for the local population of bottlenose dolphins

Coastal bottlenose dolphins live in an environment where there are no locations totally sheltered from potentially disturbing physical and acoustic stimuli. The short-term effects of boat traffic on *Tursiops truncatus* have been demonstrated in several studies and different areas (Janik and Thompson, 1996; Allen and Read 2000, Gregory and Rowden 2001, Hastie *et al.* 2003a, Sini *et al.* 2005). The real significance at the population level of small changes in behaviour, including habitat shifts, is difficult to quantify. It has, however, been demonstrated that bottlenose dolphins (Lusseau 2003a), as well as other mammals (Dyck and Baydack 2004), react differently to the

presence of a potential predators according to their gender, with females reacting more strongly than males. Such behavioural differentiation could imply a greater energetic impact on females than males. All countermeasures taken by dolphins to reduce the risk of collision and to conduct a normal social life are likely to require additional energetic costs (Wells 1993 as cited in Allen and Read 2000, Gisiner 1998, Frid and Dill 2002, Hastie *et al.* 2003a, Lusseau 2003a, Williams 2003). The noise associated with boats, which alerts dolphins to their presence and movements, may mask the dolphins' communication sounds (Au *et al.* 1985, Au 1993, Lesage *et al.* 1993, Foote *et al.* 2004) and potentially force dolphins to increase their use of echolocation and/or change the frequency, duration and intensity of their communication sounds (Richardson *et al.* 1995, Foote *et al.* 2004). Even if each single small change in behaviour requires only a small increase in energetic expenditure, the cumulative effect could seriously affect not only individual welfare, but also the population. This is especially true when a critical increase in the energetic requirements is not balanced by a comparable increase in food resources. A simple anti-predator countermeasure, such as an increase in the coalescence or size of bottlenose dolphin groups in response to boat traffic (Hastie *et al.* 2003a) could be impracticable for the Kvarnerić bottlenose dolphin population, because the available resources are unlikely to support larger group sizes.

In the Kvarnerić, the available evidence shows that the cumulative effect of boat disturbance is affecting the behaviour of bottlenose dolphins in ways that could have consequences at the population level. The situation, particularly any changes in basic demographic rates, therefore needs to be monitored carefully.

3.4.4 Conservation and management

The usefulness of determining habitat where there is a higher likelihood of dolphin presence is obvious when the purpose of a study is to identify suitable conservation and management measures. Probability maps can be very useful tools in helping to design MPA boundaries and can identify the strongest factors affecting avoidance or attraction (Cañadas *et al.* 2005). Through comparing our predicted maps of dolphin presence within the archipelago, we identified areas of special importance. In particular, there are some areas where dolphin encounter rates were high despite their proximity to the main speed boats route (black dashed shapes in Fig. 3.13 A). Besides these, the identification of recently avoided areas (Fig. 3.13 B) was fundamental for a better understanding of the possible nature of harassment.

The results show that the temporal aspect of the analyses is also important (Figure 3.10-3.12). They indicate that defining the conservation measures in a dynamic manner may provide more effective protection for the dolphins. Flexible regulations should take into account the high temporal variability in traffic within the area.

Tourism in this area represents an important source of income, both for local people and nationally. This archipelago alone receives 25% of the total number of tourists in Croatia each year (Croatia Tourism Cluster 2003). The implementation of the MPA should not compromise economics with overwhelming regulations. A healthy environment, enriched by the presence of a charismatic species, is more likely to sustain a good level of high quality tourism. This was already experienced locally in 1998 when the Adriatic Dolphin Project, was recognised as a “Tourism Promoter” by the Tourist Board of the City of Mali Lošinj.

In conclusion, we showed that applying GLMs to presence/absence data is a useful and efficient tool for conservation and management, especially in studies characterised by data collected through non-systematic effort.

3.4.5 Methodological considerations

According to a review of model evaluation methods by Boyce et al (2002), many of the usual methods for evaluating logistic regression models which deal with presence/absence data are unsuitable. This is because habitats given the value 1 are also expected to be included among the zeros. This brings a low classification success due to the fact that the predicted and the observed values are not unique. As a consequence, even an optimal model might give low values of explained variability. This seemed to be the case for some of our GLMs, especially those run on subsets of the data, as indicated by the shape of the plots of residuals. The range of variance explained by the annual models was probably due to the variability inherent in the size of each annual dataset.

We are also aware that the lack of data on additional covariates may have played an important role in not reaching a greater level of explained variability, especially those relating to prey density and movement (influenced also by oxygen dissolved in the water, water column sea temperature, sea currents, nitrogen enrichment etc.).

However, based on the data available, the water characteristics in our study area were stable over the period of the study (Croatian Environmental Agency and Institute of Oceanography and Fisheries of Split, http://baza.azo.hr/projekt_more/index.htm, first entered on the 18th of January 2005). Overall, we are confident that the results of these models are indicative of real effects on the distribution of dolphins in this area.

High temporal variability also adds to the uncertainty in predictions that do not take this into account. Nevertheless, our results seem to be powerful enough to assist the management bodies in charge of environmental heritage in defining critical habitats and factors affecting the distribution of coastal cetaceans. This indication was supported by the fact that, even when using a larger spatial scale (4 km²), the overall model results did not change, except for the lack of significance of the covariate describing the distance from the main route connecting Lošinj and Rab island. This was probably because this covariate has its effect on a scale of less than 2 km.

**CHAPTER 4: SURVIVAL AND FECUNDITY RATES OF
BOTTLENOSE DOLPHINS IN THE KVARNERIĆ**

4.1 INTRODUCTION

Knowledge of survival and fecundity rates is important to understand species' population dynamics in an ecological context, by giving an insight into population structure and resilience to environmental stressors (Rice 2001, Morris and Doak, 2002; Sibly and Hone 2002, IUCN 2005). Survival rates are also one of the key parameters for determining the long-term viability of populations (Morris and Doak, 2002; Ralls *et al.*, 2002, White *et al.* 2002). Changes in species' population growth may also reveal large-scale changes in ecosystem function or structure (Bjørnstad *et al.* 2004, McMahon *et al.* 2005). In cetacean species, knowledge of survival and fecundity helps in the understanding of life-history strategies of these long-lived species, which have low birth rates, high survival rates, and for which juvenile survival is important because of their delayed sexual maturation (Barlow and Boveng 1991, Brault and Caswell 1993, Heppell *et al.* 2000). An accurate understanding of factors affecting survival, fecundity and population viability is hence a necessary foundation for informed decision-making and improving the management of populations of protected species (Ralls *et al.* 2002).

Understanding the causal factors responsible for changes in the status of long-lived and slow-reproducing species requires long term data series, from live and/or dead animals, which are difficult to obtain and maintain logistically and financially. This is especially true for cetacean species, which typically have wide geographical ranges, and spend their entire life cycle at sea, mainly underwater. These factors explain why little is known about life history parameters of cetacean species, relative to many other species.

Mark–recapture models have been routinely used to estimate population parameters of avian, amphibian, fish and terrestrial mammal species (Akçakaya 2000). Relatively

few studies of this kind exist for cetaceans: blue (*Balaenoptera musculus*), gray (*Eschrichtius robustus*), humpback (*Megaptera novaeangliae*), northern right whales (*Eubalaena glacialis*) (Buckland 1990; Barlow and Clapham 1997; Caswell *et al.* 1999; Fujiwara and Caswell 2001; Gabriele *et al.* 2001; Zeh *et al.* 2002 Calambokidis and Barlow 2004; Mizroch *et al.* 2004; Ramp *et al.* 2005; Ramp *et al.* 2006; Bradford *et al.* 2006); sperm (*Physeter macrocephalus*) (Evans and Hindell 2004) and killer whale (*Orcinus orcas*) (Olesiuk *et al.* 1990, Brault and Caswell 1993); and bottlenose dolphins (Hersh *et al.* 1990, Sanders-Reed *et al.* 1999, Gaspar 2003; Stolen and Barlow 2003). These studies used two main approaches: a) construction of life tables either based on data from all live individually recognisable individuals comprising a population (for example, photo-identification data on killer whales) or from strandings; and b) use of mark-recapture models based on photo-identification data. In “obligate aquatic marine mammals”, such as Cetaceans and Sirenians, existing estimates of survival rate for Mysticetes, Odontocetes (*Tursiops truncatus* excluded) and Manatees, have been found to be high, as expected for long-lived “K-selected” species (Berta and Sumich 1999) (Table 4.1).

There are only two examples of classic life-tables for cetacean species, due to the inherent difficulties of collecting the full dataset required to apply this method (Olesiuk *et al.* 1990, Stolen and Barlow 2003).

Table 4.1 - Summary of survival estimates of cetaceans based on capture-recapture analysis (Standard Error and/or 95% Confidence Intervals)

<i>Mysticetes</i>			
Species	Adult ϕ	Dataset	Source
Bowhead whale (<i>Balaena mysticetus</i>)	0.98		Zeh <i>et al.</i> 2002
Grey whale (<i>Eschrichtius robustus</i>)	0.951 (0.0135; 0.917-0.972)		Bradford <i>et al.</i> 2006
Northern Right whale (<i>Eubalaena glacialis</i>)	0.99	1980	Caswell <i>et al.</i> 1999
-	0.94	1994	Caswell <i>et al.</i> 1999
Humpback whale (<i>Megaptera novaeangliae</i>)	0.951 (0.929-0.969)		Buckland 1990
-	0.957 (0.028)		Larsen & Hammond 2004
-	0.960 (0.008)		Barlow & Clapham 1997
-	0.96 (0.008)		Calambokidis & Barlow 2004
-	0.963 (0.944-0.976)	Hawai'i	Mizroch <i>et al.</i> 2004
-	0.984 (0.954-0.995)	Alaska	Mizroch <i>et al.</i> 2004
-	0.957 (0.943-0.967)	Prince William Sound	Mizroch <i>et al.</i> 2004
-	0.973-0.986		Ramp <i>et al.</i> 2005
Blue whale (<i>Balaenoptera musculus</i>)	0.85 (0.034)		Calambokidis & Barlow 2004
-	0.975 (0.960-0.985)		Ramp <i>et al.</i> 2006
<i>Odontocetes</i>			
Species	Adult ϕ		Source
Killer whale (<i>Orcinus orca</i>)	0.9986		Brault & Caswell 1993
Sperm whale (<i>Physeter macrocephalus</i>)	0.905 (0.856–0.986)	♀ Australia	Evans & Hindell 2004
-	0.885 (0.859–0.970)	♀ Japan	Evans & Hindell 2004
Bottlenose dolphin	0.942 (0.015)	Moray Firth (UK)	Sanders-Reed <i>et al.</i> 1999
-	0.994 (0.008)	Sado (Portugal) 1986-1990	Gaspar 2003
-	0.961 (0.012)	Sado (Portugal) 1991-2001	Gaspar 2003

Capture-recapture models can be used to estimate population size and birth, death and emigration rates. The basic open population capture–recapture model is the Cormack–Jolly–Seber (CJS) model, developed independently by Cormack (1964), Jolly (1965) and Seber (1965) and used to model populations subject to birth, death, emigration and immigration. In populations that can be assumed to remain unchanged over the study period, closed population models can be used to estimate population size, as presented in Chapter 6.

Various assumptions underlie basic mark-recapture models. If data from a particular population is known to violate some assumptions, it may be possible to accommodate this in models. For example, there are models that allow for temporary emigration and rare visitors or “transients” (White *et al.* 1982, Lebreton *et al.* 1992, Pollock 2002). The basic assumptions of mark-recapture methods as applied to cetaceans are reviewed in Hammond (1986), Hammond *et al.* (1990), and Evans and Hammond (2004). They are:

1. Marked animals are not affected (either in life expectancy or behaviourally) by being marked;
2. Marks are not lost and are always reported correctly on recapture;
3. Marked and unmarked animals mix completely in the population between each sampling occasion;
4. Within a sampling occasion, all animals (marked and unmarked) have the same probability of being captured;
5. Sampling events are carried out within discrete time intervals and the duration of each sampling event must be small in relation to the total duration of sampling programme.

The violation of these assumptions may invalidate mark-recapture analyses, unless properly modelled. Assumptions may be relaxed by using more complex models; this will, however, inevitably lead to an increase in the variability of parameter estimates (Cormack, 1979; Begon, 1983). The proliferation of parameters in more complex models makes it very difficult to apply such models to small datasets. As a general rule, parsimony, the use of the smallest possible number of parameters to model a population, should be used.

Since their initial development, the basic mark-recapture models have been extended to the benefit of biologists and managers. Examples include: several versions of Pollock's robust design, Bayesian methods, multi-state models that allow for time-varying categorical covariates of capture, and joint models allowing for the inclusion of observations of animals between capture occasions. Reviews of these topics are given by White *et al.* (1982), Lebreton *et al.* (1992), Schwarz and Seber (1999) and Pollock (2002).

The estimation of population parameters using mark-recapture methods is made difficult by heterogeneity of capture probabilities due to biological differences between individuals (violation of assumption 4, above). Closed population models used to estimate population size that account for heterogeneity are available (Chao 1987, 1989), but unequal capture probabilities are difficult to model in open models. For long-term studies, the best way to tackle the problem of unequal capture probabilities seems to be the use of the Pollock's robust design (Kendall and Nichols 1995, Kendall *et al.* 1995, Kendall 2001).

Pollock's robust design (Pollock 1982) - extended by Kendall *et al.* (1995, 1997) - combines the use of closed population models applied to data from secondary sampling occasions (e.g. months) with the use of open population Cormack-Jolly-Seber (CJS) models across primary periods (e.g. years). The CJS method for estimating survival rate tends to be robust to heterogeneity in capture probability (Kendall 2001). Closed-population methods include abundance estimators that are robust to this heterogeneity (Chao 1989). Therefore, by using closed population estimators for abundance and CJS estimators for survival rate, the overall analysis is more robust to heterogeneity. This model, originally developed to reduce the effects of heterogeneity on estimates of abundance, has been also extended to differentiate

between *in situ* population growth and re-immigration, a measure of the residence status of individuals (Nichols and Pollock, 1990). Modelling options are also available to separate temporary and permanent emigration from death (Schwarz and Stobo 1997; Kendall and Nichols 1995; Kendall and Bjorkland 2001, Lindberg *et al.* 2001).

For cetacean species, the most common sampling design is to “capture” and “recapture” individuals using photo-identification (Hammond *et al.* 1990) during a short period (field season) each year, for multiple years, in order to estimate annual survival rate,. However, in highly mobile species that may be characterised by complex population structure and fluid social structures, many details must be considered before the most appropriate way to collect and model data can be determined.

A long-standing problem of capture–recapture models involves the issue of heterogeneity introduced by transient individuals passing through the sample area at the time of sampling. These animals may have no chance of returning in subsequent years (permanent emigration), or they may be part of the population but are not always present in the study area (temporary emigration). The emigration process can be described in three ways:

- i) Markovian temporary emigration (non-random emigration), where the probability of an animal of being captured at time $t + 1$ depends on whether it was available for capture at time t ;
- ii) Permanent emigration, a special case of Markovian emigration, where the probability of subsequent capture is zero for animals available for capture at time t ;

- iii) Random temporary emigration, which arises by constraining the Markovian movement parameters so that the probability of capture at time $t + 1$ does not depend on whether the animal was available for capture at time t .

The existence of permanent emigration produces a confounding effect between emigration and mortality (Williams *et al.* 2002), because it violates the assumption that all animals alive at time t have the same chance of survival and capture until time $t+1$ (Lebreton *et al.* 1992). A mixture model for survival of unmarked animals that accounts for transients (Pradel *et al.* 1997) has recently been applied to the results of humpback and blue whales studies (Mizroch *et al.* 2004, Ramp *et al.* 2005, Ramp *et al.* 2006). Temporary emigration is characterised by individuals not being available for sampling in the study area at every sampling occasion. When temporary unavailability for detection is present and random, it is confounded with survival; whereas when this unavailability is Markovian, bias in other parameters will occur if some constraints are not made (Kendall *et al.* 1997). Kendall *et al.* (1997) found that Markovian temporary emigration, if not considered, tends to bias survival estimates and capture probabilities down, especially those toward the end of a study. Such biases are considerable for capture probabilities, but usually small for survival estimates (Kendall *et al.* 1997, Manly *et al.* 1999). Pollock's robust design can be used to estimate the rate of transitions to and from an unobservable state and relax the assumption on emigration (Kendall and Nichols 1995, Kendall *et al.* 1997, Schwarz and Stobo 1997; Kendall 2001; Lindberg *et al.* 2001; Bailey *et al.* 2004 a, b, c; Bradford *et al.* 2006).

As for all marine mammals, bottlenose dolphin life history traits are characterised by low fecundity, delayed maturity and high annual survival (Leatherwood and Reeves 1990, Berta and Sumich 1999). Robust estimates of these parameters can improve our

understanding of their life histories and are essential for effective conservation.

Estimates of adult survival rate are particularly important in long-lived vertebrates, including for bottlenose dolphins (Gaspar 2003), due to the sensitivity of population growth rate to this parameter (see for example, Gaillard *et al.* 1998, Frisk *et al.* 2004, Runge *et al.* 2004). Estimates of sub-adult or juvenile survival are also important because of the late attainment of maturity in many species, and this can have direct implications for the effectiveness of management (Beissinger and McCullough 2002, Morris and Doak 2002; IUCN 2005).

As demonstrated by Mizroch *et al.*'s (2004) study of humpback whales in Hawai'i, south-eastern Alaska and Prince William Sound, the use of different sites for feeding and breeding by individuals can lead to differences in apparent survival rates.

Significant differences in adult survival rates between populations that are linked to anthropogenic pressure or exploitation, as is the case for the Florida manatee (Langtimm *et al.* 1998) and Northwest Pacific sperm whale females (Evans and Hindell 2004), raise serious concerns about the status of populations, with clear management implications.

In this chapter, data collected during nine years of sampling on a naturally well-marked population of bottlenose dolphins in the Kvarnerić region of Croatia are used to estimate survival rates. These data provide an opportunity to generate important baseline information for developing conservation strategies and actions for this species in this area. These estimates are used in a Population Viability Analysis (PVA) in Chapter 6. This is the first study to provide data of this kind for the Mediterranean basin and one of only a few world-wide (Hersh *et al.* 1990, Sanders-Reed *et al.* 1999, Gaspar 2003; Stolen and Barlow 2003).

Estimates of abundance obtained through the robust design and other methods are presented in Chapter 5. Fecundity rates - which indicate the average rate of reproduction of the Kvarnerić bottlenose dolphins' population and reflect its capacity to grow - are also estimated and used in Chapter 6 for PVA.

4.2 MATERIALS AND METHODS

Definitions and survey, photo-identification, and photo-matching methodologies are described in Chapter 2.

4.2.1 Photo-identification data and age class definition

“**Calves**” in this analysis were defined as all individuals with a presumed age of less than 4-5 years, that are always encountered in the same group as their presumed mothers (defined as “Newborns”, “Calves”, and “Juveniles” in Chapter 2). “**Adults**” were defined as all other independent individuals, with an estimated body length between 2.5 and 3 m. Independent individual means a weaned animal, not necessarily observed in the same group of its presumed mother. This definition, therefore, includes a proportion of individuals that have left their mothers but have not yet become mature.

Unmarked dolphins become marked over time (Wursig and Jefferson 1990), although usually not during their first 4-5 years of life, and the severity of marking increases with time. The number of well- and poorly-marked individuals was monitored throughout the study period, in order to detect potential trends. The acquisition of long-lasting marks in cetaceans is cumulative, with males usually more involved in aggressive interactions with conspecifics (Wursig and Jefferson 1990, Dufault and

Whitehead 1995, Wilson *et al.* 1999b, Connor *et al.* 2000). Hence, well-marked dolphins will tend to be older individuals and are more likely to be males or non-reproductive females (because reproductive females are likely to have been seen with a calf). Immature animals are more likely to be unmarked or poorly-marked.

4.2.2 Estimation of survival and temporary emigration rates

Pollock's robust design (1982) with Huggins' estimator was used to calculate survival rates and abundance estimates, using nine years of data. Abundance estimates are presented and discussed in Chapter 5. A schematic diagram of Pollock's robust design is presented in Fig. 4.1.

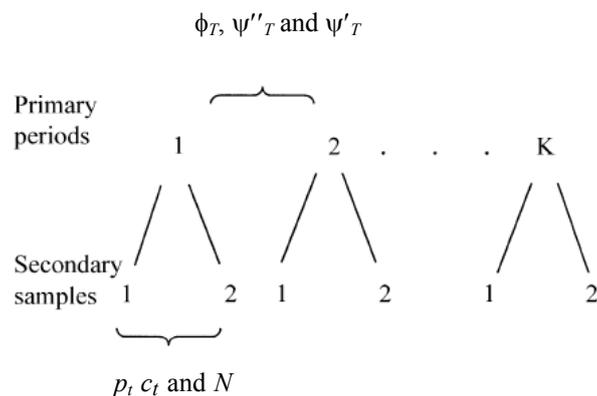


Figure 4.1 - Schematic diagram of Pollock's robust design. Within each primary period, there are multiple secondary sampling occasions with occasion-specific capture probabilities. Survival rates (ϕ_T) and temporary emigration parameters (ψ''_T and ψ'_T) are calculated between primary periods (T); abundance estimates (N) and occasion-specific capture (p_t) and recapture (c_t) probabilities are estimated using data from secondary sampling occasions (t). See text for definition of parameters.

Because mark-recapture studies of cetaceans do not involve a real capture, but rely on remote sampling using natural markings, there is general agreement that recapture probabilities are not affected by the first capture (i.e. there are no trap-shy vs. trap-

happy effects) (Hammond *et al.* 1990, Wilson *et al.* 1999b, Read *et al.* 2003a, Bradford *et al.* 2006). Therefore in all models p_t was set equal to c_t and generally referred to as capture probability.

Huggins' model (Huggins 1989, 1991) allows the estimation of closed population size (N) from capture and recapture probabilities (p and c), and the use of individual covariates to model p and c .

For the intervals between primary periods the following parameters are estimated:

- ϕ_T is the probability that a member of the population in period T survives and is still a member of the population in period $T+1$;
- ψ''_T and ψ'_T are the probabilities that a member of the population in period T is unavailable for detection (e.g., outside the study area), given that it was available or unavailable, respectively, for capture in period $T-1$; ψ''_T and ψ'_T represent temporary emigration and probability of remaining unavailable, of members of the population, respectively. When temporary emigration is random $\psi''_T = \psi'_T$, whereas if $\psi''_T \neq \psi'_T$, temporary emigration is called Markovian or non-random and the availability of a given member of the population is conditional on its presence or absence in the previous year.

During secondary sampling occasions a closed model is used to estimate the capture probabilities (p_t – the probability that an animal is available for capture during period t) for each primary period. All combinations of the above parameters, either constant (·) or time varying (T for primary periods and t for secondary sampling occasions) were explored, according to the following assumptions:

1. The population is assumed closed to immigration, emigration, births, and deaths within primary periods.
2. Naturally marked individuals are “captured” in secondary sample occasions and assumed identified without errors.
3. There is no behavioural response to “capture” (i.e. $p_t = c_t$)

4. All individuals in the population have equal capture probability during each secondary sampling occasion, regardless of their capture history.
5. All individuals used the area within the study period, but not necessarily every year (allowing for temporary emigration).
6. Temporary emigration can be either random ($\psi''_T = \psi'_T$) or non-random ($\psi''_T \neq \psi'_T$).

All mark-recapture analyses were run on Mark 4.2 (www.cnr.colostate.edu/~gwhite/mark/).

Models were evaluated using the Akaike Information Criterion, adjusted for small sample size (AICc), an index of model fit (Buckland *et al.* 2001). The model with the lowest AICc score optimises the trade-off between bias and precision by penalising the estimated likelihood by the number of model parameters (Burnham and Anderson 1998). The difference in AICc between any given model and the most supported model (ΔAICc) was used to evaluate relative model fit. Models within a ΔAICc of ≤ 2 were considered to be well supported by the data (Burnham and Anderson 1998).

For comparisons between two survival rates (a and b) a simple z -test of significance was used as follows:

$$z = \frac{\hat{\phi}_a - \hat{\phi}_b}{\sqrt{\text{var}(\hat{\phi}_a) + \text{var}(\hat{\phi}_b)}}$$

with $z > 1.96$ and $z > 1.645$ indicating significance levels of 95% and 90%, respectively.

4.2.3 Estimation of fecundity rate

Seasonality of births was explored using data only from instances of photographed newborn animals assignable to a specific mother (see Chapter 2 for definition of

newborn). All other fecundity rate analyses were carried out on a selected group of mothers seen in more than six different years (defined as “residents”), either poorly or well-marked. The annual number of calves born to selected mothers was assessed through photo-identification.

For the purpose of estimating fecundity rates, the capture histories of these animals were corrected according to the following rules:

1. In the case of animals seen for the first time as presumed yearlings, the year of birth was assumed to be the previous year.
2. Given a gestation period of one year, a mother having a newborn calf in a given year was assumed to be alive and mature in the previous year.

The annual **Fecundity Rate** was calculated by dividing the number of newborn calves born to the selected sample of mature females in a particular year by the number of those females known to be alive in that year.

The **Inter-Calving Interval** was calculated as the reciprocal of mean Fecundity Rate.

In order to estimate apparent survival of calves, the Cormack-Jolly-Seber model was used on corrected capture histories of a selection of calves (see below). The only assumption was constant capture probability $[p(\cdot)]$. Survival could either be constant, $\phi(\cdot)$, or vary over time, $\phi(T)$.

In order to estimate apparent survival at *age 1*, *age 2*, *age 3*, *age 4*, the capture histories of calves of the above mentioned selection of mothers were used.

4.3 RESULTS

4.3.1 Photo-identification surveys and exploratory analysis

Photo-identification surveys were conducted over the period 1995-2003. A total of 625 dedicated surveys resulted in 370 photo-identification encounters. Annual research seasons were used as 9 primary periods; data were pooled monthly within research seasons to provide 50 secondary sampling occasions (Table 4.2).

Table 4.2 - Total number of secondary sampling occasions (months dedicated to photo-identification) for each primary period (year).

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
No of months	7	6	6	7	4	4	5	6	5

The annual photo-identification effort in good survey conditions varied from 44 to 90 research days (Fig. 4.2). Monthly effort pooled over years is shown in Fig. 4.3. Data from February, March and April were excluded because of very low effort (2, 3 and 12 days respectively).

The annual encounter rate per day ranged between 0.45 and 0.76 with no obvious trend (Fig. 4.2). This pattern was highlighted by deviation from a linear relationship between the annual total number encounters and the total effort (Fig. 4.4a). The pooled monthly data showed an almost constant encounter rate, except for June, when encounter rate was markedly lower (Fig 4.3). This was confirmed by the positive correlation between number of encounters and effort (Fig. 4.4b), with June lying well below the regression line.

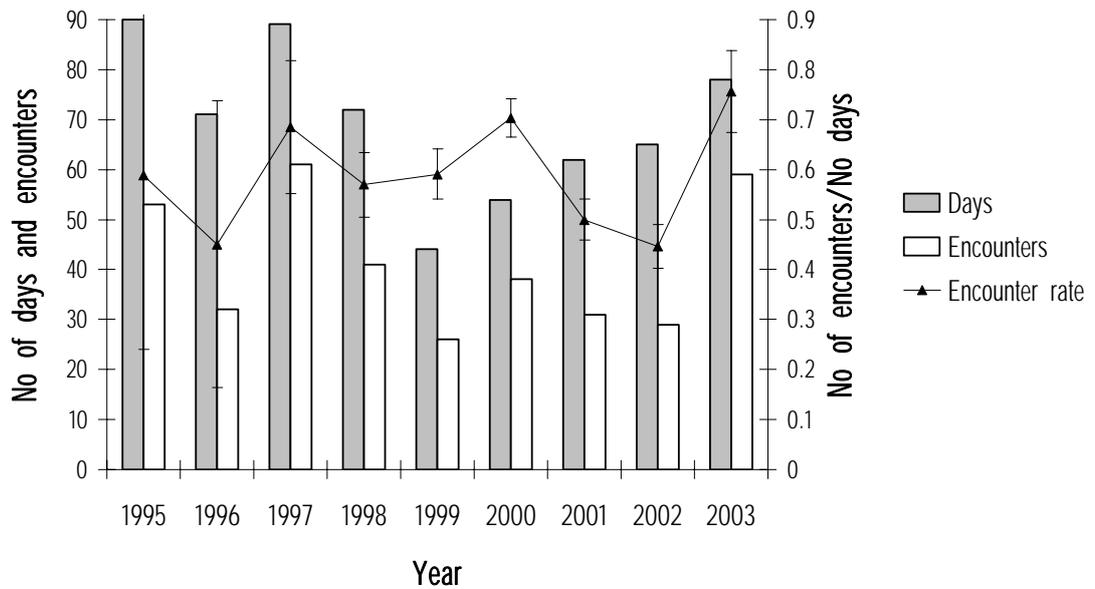


Figure 4.2 - Total number of dedicated photo-identification surveys conducted each year, the number of encounters with dolphins each year, and mean annual encounter rate (encounters/per survey day) \pm binomial standard error.

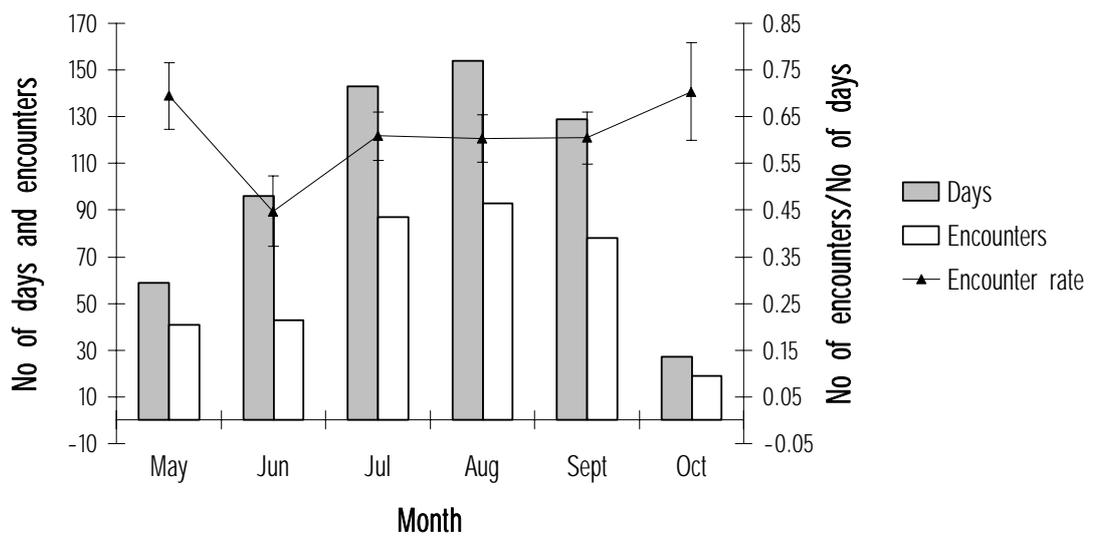


Figure 4.3 - Total number of dedicated photo-identification surveys and encounters with dolphins in each month during the study period, together with encounter rate per day \pm binomial standard error.

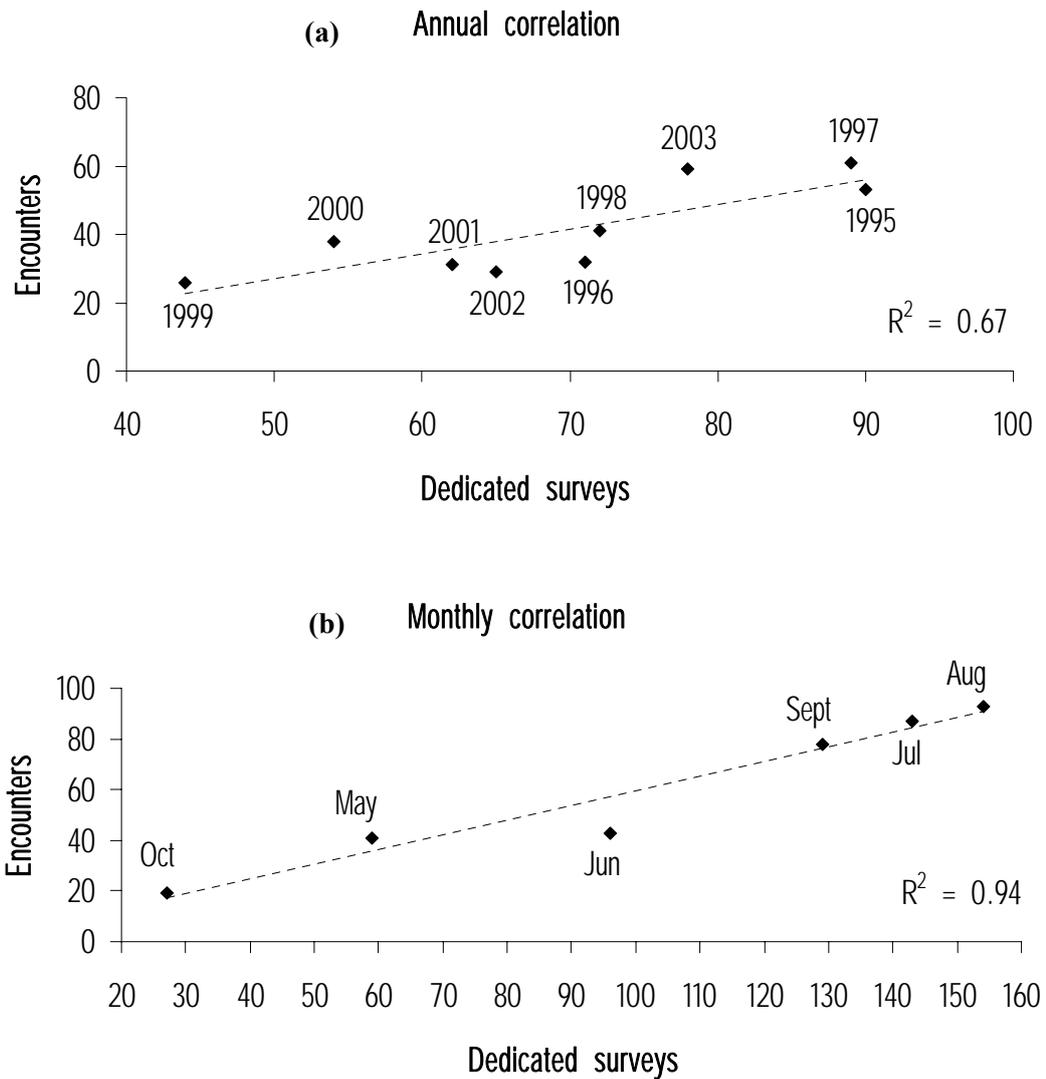


Figure 4.4 - Relationship between number of dedicated photo-identification surveys and encounters, on an annual (a) and a monthly basis (b)

The total number of animals identified each year was fairly constant over the study period (Fig. 4.5), although it was low in 1999, the year with the lowest effort (days at sea in good searching conditions). The ratio between the total annual number of poorly-marked and well-marked individuals declined slightly from 1995 to 1997, and increased between 1999 and 2003, with 1998 a clear outlier of the first quinquennium (Fig. 4.6).

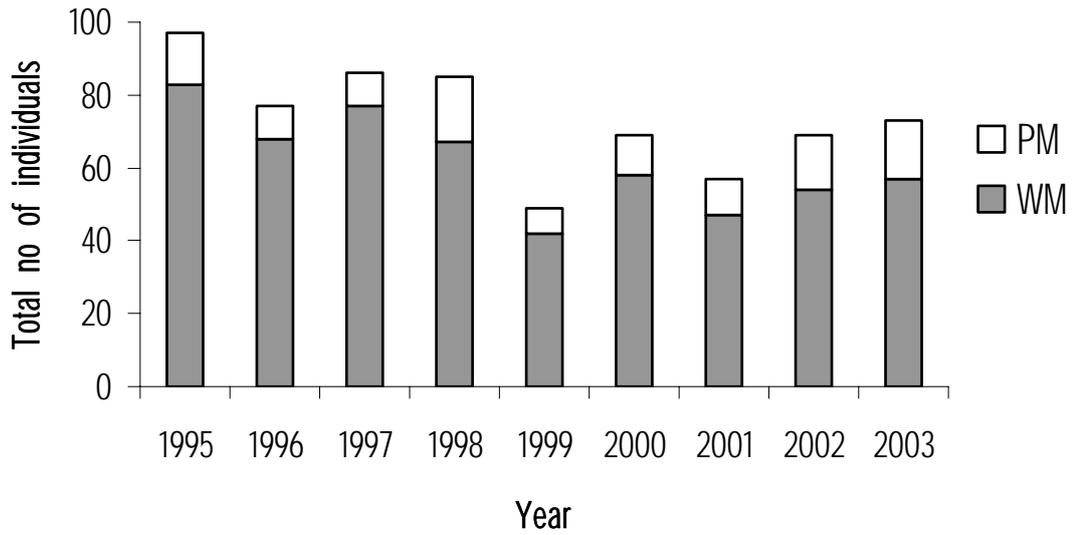


Figure 4.5 - Total number of individuals identified annually. Key: WM=well-marked individuals, PM=poorly-marked individuals.

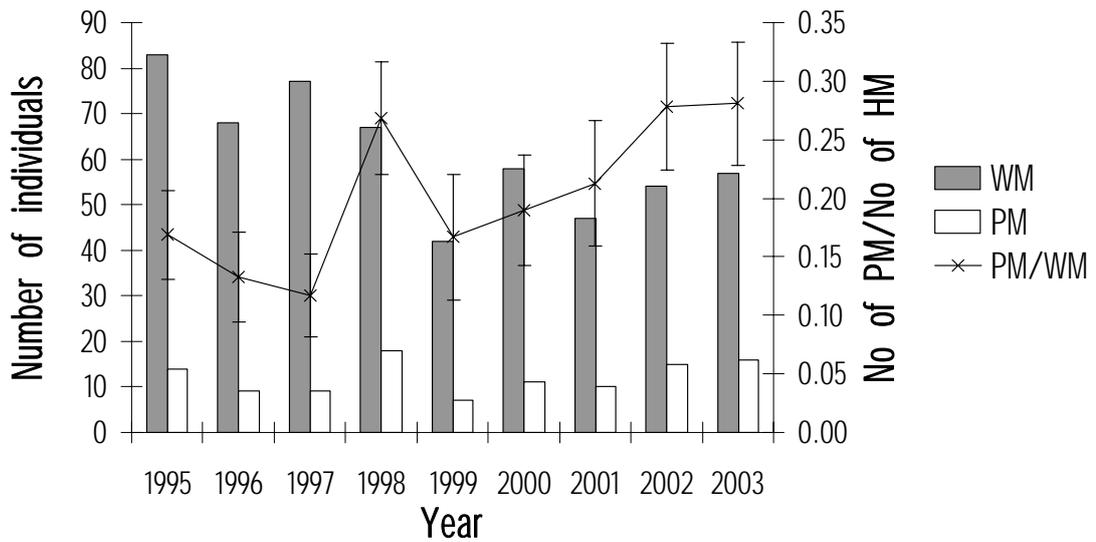


Figure 4.6 - Number of individuals identified annually and binomial standard errors. Key: WM=well-marked individuals, PM=poorly-marked individuals

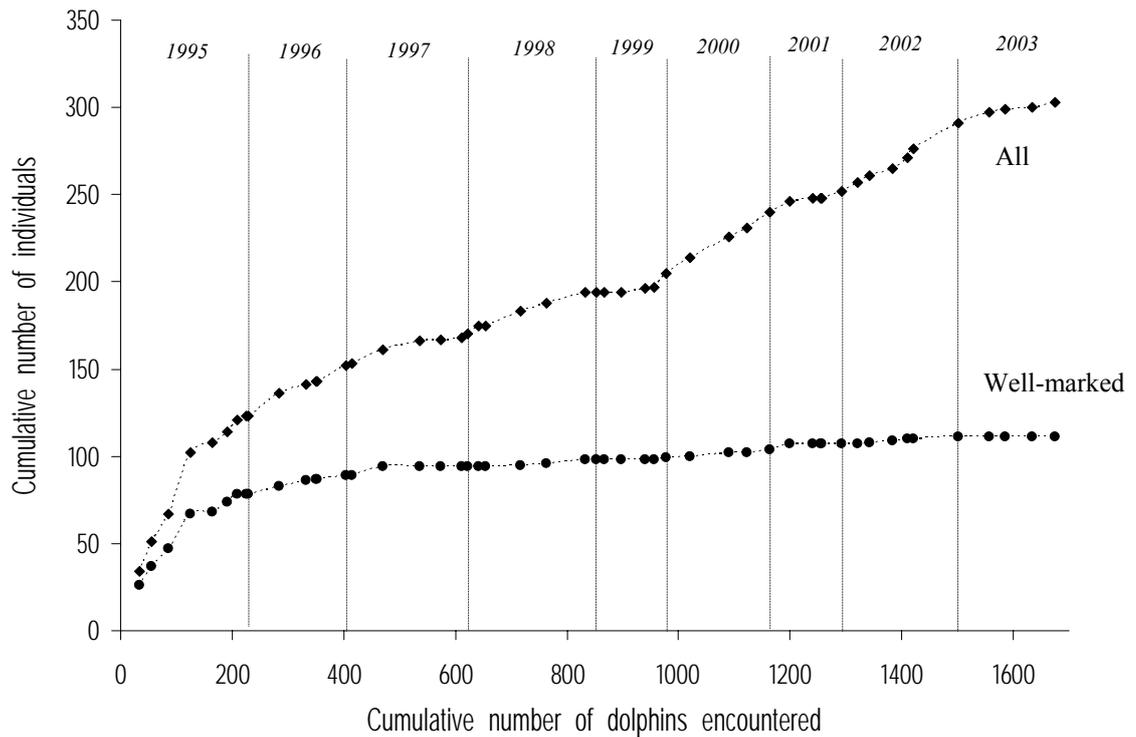


Figure 4.7 - Discovery curves showing the number of individuals identified against the cumulative number of dolphins encountered during the study. Line “All” is the curve for all animals (poorly and well-marked)

The discovery curve for well-marked individuals (Fig. 4.7) suggests that the study population of bottlenose dolphins was closed to permanent immigration. Between 1996 and 2003, when the number of photographed individuals increased from 210 to 1,695, the number of identified individuals increased by less than one animal per year (mean=0.74; SD=0.51). This number is well below the average number of newborn calves per year (mean = 4.2, see Section 4.3.3).

The curve for all identifiable individuals (curve “All” in Fig. 4.7) does not approach an asymptote. However, after 1995 the number of photo-identified individuals increased by less than 5 per year (mean=4.59; SD=2.18).

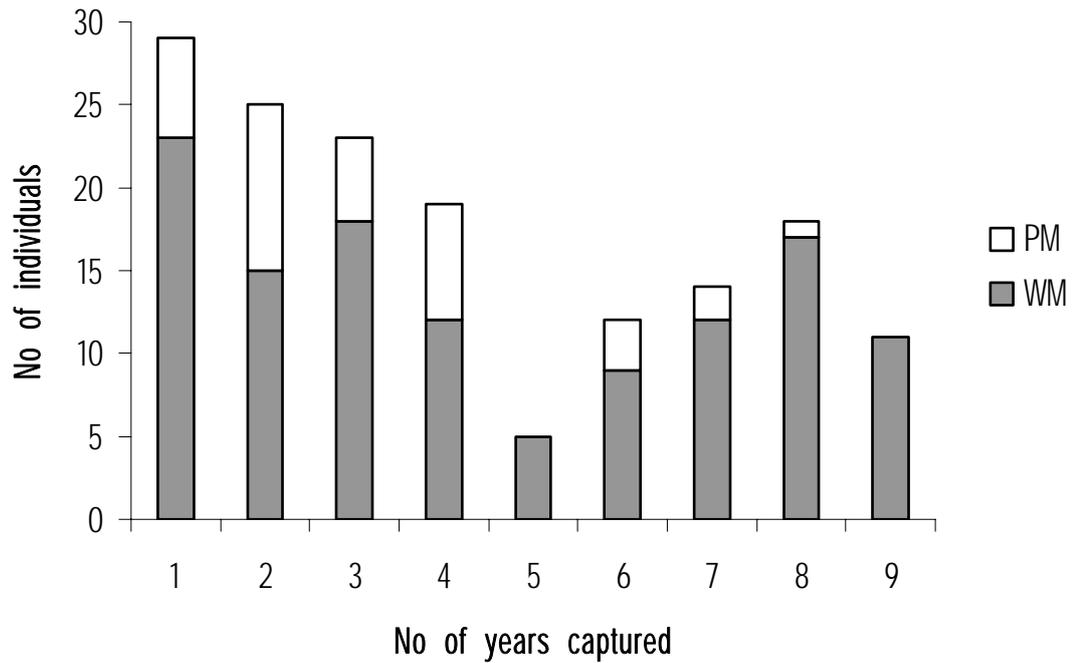


Figure 4.8 - Distribution of capture frequencies for poorly-marked (PM) and well-marked (WM) bottlenose dolphins

The distribution of capture frequencies (Fig. 4.8) for poorly-marked and well-marked dolphins shows that most individuals were seen a few times or many times. This pattern is consistent with heterogeneity of capture probabilities with two groups of individuals with different capture probabilities. A possible contributing factor to this heterogeneity is that some individuals prefer geographical regions that were not sampled representatively within the study area. For instance, most dolphins encountered off the west coast of the Cres-Lošinj islands were seen only once. By excluding these eight encounters, eighteen capture histories of dolphins were deleted from the analyses as a result and heterogeneity in the data was slightly reduced (Fig. 4.9).

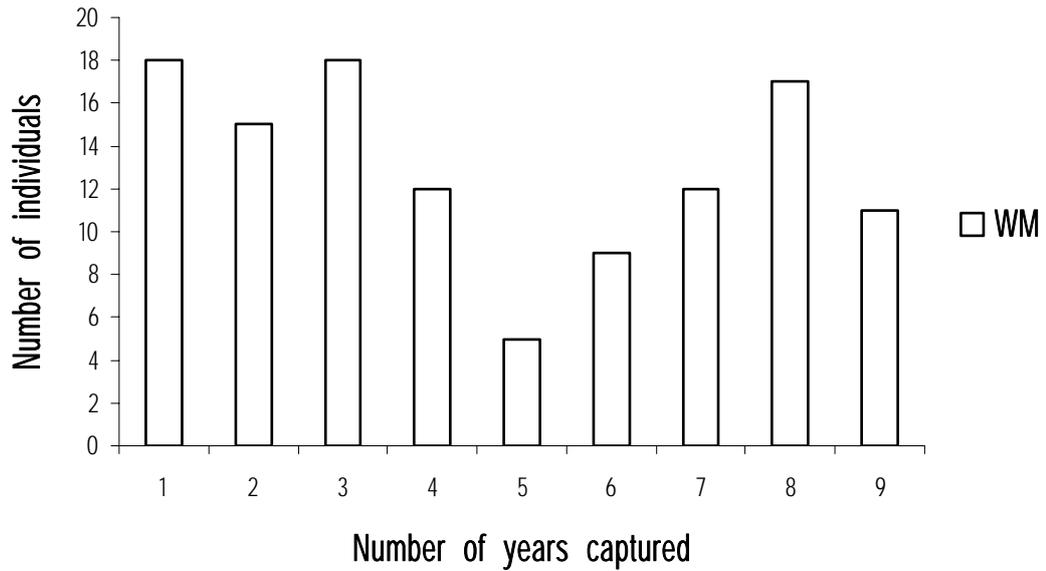


Figure 4.9 - Distribution of captures frequencies for well-marked animals only, excluding all sightings off the west coast of Lošinj island

Following these adjustments the final dataset for analysis was composed of a total of 110 well-marked dolphins, 51 of known gender (42 females and 9 males). Complete capture histories of these individuals, between 1995 and 2003, are presented in Fig. 4.10.



Figure 4.10 - (continued). Capture histories of well-marked bottlenose dolphins; years (primary periods) and progressive number of months (secondary sampling occasions) are indicated, as well as the gender, if known

4.3.2 Adult survival rates and temporary emigration

Several models to estimate survival rate, allowing temporary emigration, were applied to the complete dataset and two subsets. The first subset included capture histories of 42 known females (two of which never observed with calves; this study and Bearzi *et al.* 1997); and the other included capture histories of the 9 known males together with the remaining 59 dolphins of unknown gender, which were presumed to be mainly males and to a lesser extent immature females. No calves were included in these datasets.

4.3.2.1 All animals

In order to reduce the number of parameters to be calculated through mark-recapture modelling, monthly capture probabilities in different years were explored to check if they could be fixed as constant parameters in all years. All months, except May and June, showed appropriate conditions to apply such a simplification, based on the width of their 95% CI and on the plausibility of a common average value (Fig. 4.11). Also any model run with this restriction gave a better AICc (Δ AICc up to 12). An additional restriction was applied to the last two years which were pooled together for the calculation of survival and temporary emigration rates, mainly for two reasons: a) the model showed the tendency to fix estimates for the last year, losing information; b) the survival estimate for the last year may be negatively biased by heterogeneity (Buckland 1990).

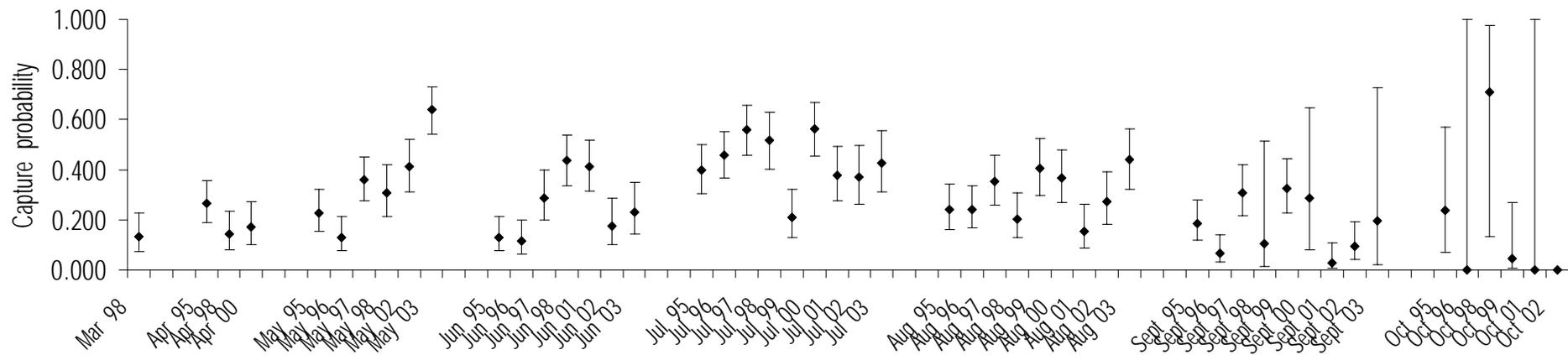


Figure 4.11 - Variation of monthly capture probabilities for Kvarnerić bottlenose dolphins in different years with 95% CI

Table 4.3 – Fit of capture-recapture models to photo-identification data from the entire bottlenose dolphin data set. ϕ ,= survival, ψ'' = probability of temporary emigration, ψ' = probability of remaining unavailable, p = capture probability. T indicates time-dependence between primary periods, and t within primary periods.

Model	AICc	Δ AICc	AICc weight	No. parameters	Deviance
1A $\phi(T) \psi''(T) \psi'(T) p_{monthly}(t)$	4389.39	0.00	0.631	34	6685.38
2A $\phi(T) \psi''=\psi'(T) p_{monthly}(t)$	4392.43	3.04	0.138	31	6694.81

All other models had Δ AICc > 4

Using data from all animals only Model 1A, in which survival and non-random temporary emigration parameters varied over time and capture probabilities varied with month, received most support from the data (Table 4.3). The next best Model (2A) included random emigration. Parameter estimates from Model 1A are given in Table 4.4.

Table 4.4 - Estimates of survival and emigration probabilities with standard errors (SE), coefficient of variation (CV) and 95% confidence intervals (95% CIs) obtained from Model 1 A (see Table 4.3). Key: ϕ =apparent survival, ψ'' =temporary emigration, ψ' = probability of remaining unavailable. Note: parameters marked with * are fixed by the model not estimated.

All well-marked dolphins				
Parameter	Estimate	SE	CV	95% CI
ϕ_{96}^*	1.000	-	-	-
ϕ_{97}	0.925	0.036	0.039	0.816 - 0.972
ϕ_{98}	0.938	0.042	0.045	0.785 - 0.984
ϕ_{99}	0.825	0.054	0.065	0.694 - 0.908
ϕ_{00}	0.921	0.048	0.052	0.763 - 0.977
ϕ_{01}	0.929	0.046	0.050	0.768 - 0.981
ϕ_{02-03}	0.914	0.029	0.032	0.836 - 0.957

Table 4.4 - (Continued) Estimates of survival and emigration probabilities with standard errors (SE), coefficient of variation (CV) and 95% confidence intervals (95% CIs) obtained from Model 1 A. Key: ψ'' =temporary emigration, ψ' =probability of remaining unavailable.

Parameter	Estimate	SE	CV	95% CI
$\psi''96$	0.123	0.061	0.496	0.044 - 0.299
$\psi''97$	0.076	0.045	0.592	0.023 - 0.223
$\psi''98$	0.165	0.057	0.345	0.080 - 0.308
$\psi''99$	0.158	0.087	0.551	0.050 - 0.404
$\psi''01$	0.300	0.072	0.240	0.179 - 0.458
$\psi''02-03$	0.088	0.046	0.523	0.031 - 0.227
$\psi'98$	0.714	0.162	0.227	0.346 - 0.922
$\psi'99$	0.154	0.144	0.935	0.020 - 0.614
$\psi'01$	0.178	0.122	0.685	0.040 - 0.526

The well-marked adult bottlenose dolphins showed rather low apparent survival rates (<0.94), appreciable temporary emigration rates (0.08-0.30) and a highly variable probability of remaining unavailable (re-immigration rate). Survival estimates differed significantly only between 1998 and 1999 ($p < 0.05$, $z = 1.65$ at 90% level of significance) (Fig 4.12). Only three values of the probability of remaining outside the study area were estimated, the value for 1998 was significantly higher than the others (Fig. 4.13).

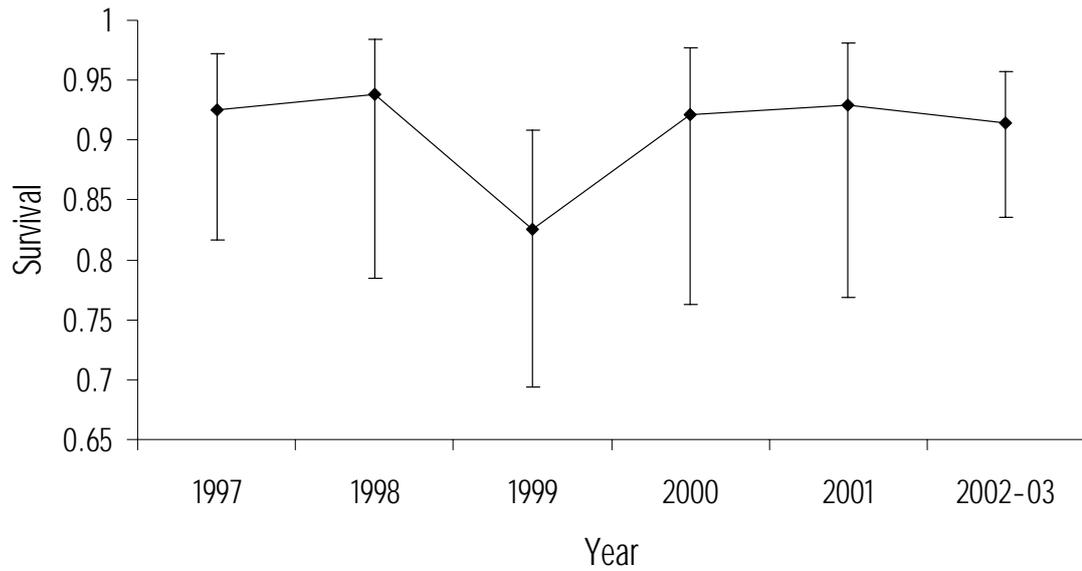


Figure 4.12 – Variation in apparent survival rate of well-marked dolphins over time. Vertical lines indicate 95% CIs

Capture probabilities were higher in summer months, with a maximum in August (Fig. 4.13A). They were particularly variable in May and June. May capture probabilities for 2002 and 2003 appear to be higher than in previous years (Fig. 4.13B).

Unfortunately the lack of estimates for some years impairs the possibility to make specific inferences on their trends.

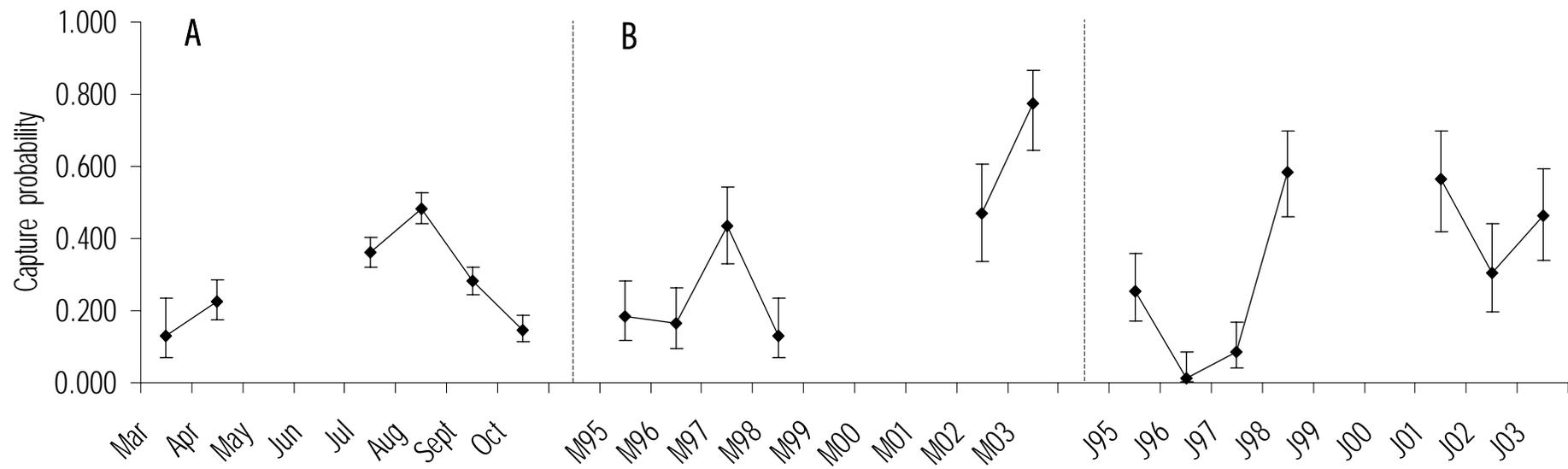


Figure 4.13 - Capture probabilities of Kvarnerić bottlenose dolphins within secondary sampling occasions (Model 1A, Table 3) and 95% CI. May and June are identified by their first capital letter (M or J) and the year (95 and following years)

4.3.2.2 Known females

For well-marked known females, four models received substantial support from the data (Table 4.5). All involved time-varying survival and capture rates, but they included different types of temporary emigration, suggesting that the dataset is inadequate to allow the form of this process to be identified.

Table 4.5 - Model fits to the subset of known females. ϕ , ψ'' , ψ' , p are survival, temporary emigration, probability of remaining unavailable and capture parameters, respectively. Notation (T) or (t) means time-dependent between or within primary periods, with the above explained constrains, (·) means constant.

Model	AICc	Δ AICc	AICc weight	No. parameters	Deviance
1F $\phi(T) \psi''(T) \psi'(T) p_{monthly}(t)$	1956.18	0.00	0.263	32	2774.28
2F $\phi(T) \psi''(\cdot)\psi'(\cdot) p_{monthly}(t)$	1956.54	0.36	0.220	25	2790.56
3F $\phi(T) \psi''=\psi'(T) p_{monthly}(t)$	1957.39	1.21	0.144	29	2782.38
4F $\phi(T) \psi''=\psi'(\cdot) p_{monthly}(t)$	1957.76	1.58	0.137	25	2791.78
5F $\phi(\cdot)\psi''=\psi'(T) p_{monthly}(t)$	1958.83	2.65	0.080	25	2792.85

All other models had Δ AICc > 3.

Because models 1F-4F all fell within 2 Δ AICc, model averaging was carried out to estimate survival rates. This procedure allowed the inclusion of model uncertainty in the estimate of precision of the annual survival rates, producing unconditional estimates of variances and standard errors (Table 4.6).

Table 4.6 - Model averaged estimates of survival for well-marked females with standard errors (SE), coefficient of variation (CV) and 95% confidence intervals (95% CIs) obtained with model averaging of models 1F, 2F, 3F and 4F.

ϕ =apparent survival. Note: parameters marked with * are fixed by the model and not estimated.

well-marked females

Parameter	Estimate	SE	CV	95% Cis
ϕ_{96}^*	1.000	-	-	-
ϕ_{97}	0.940	0.043	0.045	0.781 - 0.986
ϕ_{98}	0.970	0.047	0.048	0.577 - 0.999
ϕ_{99}	0.842	0.068	0.081	0.662 - 0.936
ϕ_{00}^*	1.000	-	-	-
ϕ_{01}	0.912	0.038	0.042	0.803 - 0.963
ϕ_{02-03}	0.989	0.020	0.020	0.703 – 1.000

Apparent survival rates of known females ranged between 0.842 and 0.989 (Table 4.6). Estimates of time-varying temporary emigration (Models 1F and 3F) were highly variable and are not presented. Estimates of time-invariant temporary emigration rates are presented in Table 4.7. The rate was similar (9-10%) when emigration was assumed to be random or non-temporary emigration. However, the probability of remaining unavailable for capture, estimated explicitly in Model 2F, was much higher than the value inferred from Model 4F (in which it is assumed to be the same as the probability of emigration).

Table 4.7 - Estimates of temporary emigration parameters (ψ'' and ψ') with standard errors (SE) and 95% confidence intervals (95% CIs) from models 2F and 4F. ψ'' =temporary emigration, ψ' = probability of remaining unavailable.

well-marked females				
Parameter	Estimate	SE	CV	95% CI
Model 2F				
ψ''	0.090	0.034	0.378	0.041 - 0.183
ψ'	0.253	0.149	0.589	0.067 - 0.613
Model 4F				
ψ	0.101	0.037	0.366	0.048 - 0.200

Capture probabilities of females differed within primary periods (Fig. 4.14) and are described below together with those of animals of unknown gender.

4.3.2.3 Animals of unknown gender and males

For dolphins of unknown gender and males, two models (1U, 2U) received substantial support from the data (Table 4.8). Both involved constant survival rate and capture probabilities that varied over time, but they had different types of temporary emigration. Model averaging was used to estimate apparent survival from these two models.

Table 4.8 - Model fits to subset of well-marked individuals of unknown gender and males. ϕ , ψ'' , ψ' , p are survival, temporary emigration, probability of remaining unavailable and capture parameters, respectively. Notation (T) or (t) means time-dependent between or within primary periods, (·) means constant.

Model	AICc	Δ AICc	AICc weight	No. parameters	Deviance
1U $\phi(\cdot)\psi''=\psi'(T) p_{monthly}(t)$	2444.69	0.00	0.417	24	3320.57
2U $\phi(\cdot)\psi''(\cdot)\psi'(\cdot) p_{monthly}(t)$	2445.26	0.57	0.313	21	3327.62
3U $\phi(T) \psi''=\psi'(T) p_{monthly}(t)$	2447.04	2.35	0.129	29	3311.99

All other models had Δ AICc > 19.

The apparent survival for well-marked male bottlenose dolphins and those of unknown gender was 0.902 (SE=0.019; CV=0.021; 95% CI=0.858 – 0.993). Estimates for random (Model 1U) and non-random temporary emigration (Model 2U) are presented in Table 4.9.

Table 4.9 - Estimates of emigration probabilities with standard errors (SE) and 95% confidence intervals (95% CIs) obtained from the best model for well-marked dolphins of unknown gender and males (Model 1U, Table 4.8). ψ'' =temporary emigration, ψ' = probability of remaining unavailable.

Unknown gender				
Parameter	Estimate	SE	CV	95% CI
Model 1U				
ψ''_{96}	0.088	0.076	0.864	0.015 – 0.382
ψ''_{98}	0.300	0.078	0.260	0.171 – 0.471
ψ''_{99}	0.289	0.098	0.339	0.137 – 0.509
ψ''_{01}	0.250	0.084	0.336	0.122 – 0.444
ψ''_{02-03}	0.113	0.068	0.602	0.033 – 0.327
Model 2U				
ψ''	0.141	0.033	0.234	0.088 – 0.218
ψ'	0.460	0.134	0.291	0.227 – 0.711

The estimated apparent survival rates for well-marked male bottlenose dolphins and those of unknown gender was significantly lower ($p < 0.05$, $z = 2.18$ at 95% level of significance) than the mean apparent survival rates of well-marked known females ($\phi = 0.950$, SE=0.022, $n = 7$). The probability of emigrating ranged between 8% and 30% (Table 4.9).

Figure 17 shows the capture probabilities for known females and animals of unknown gender, from models F1 and U1. Female capture probabilities were consistently but not significantly lower than those of dolphins of unknown gender (Fig. 4.14).

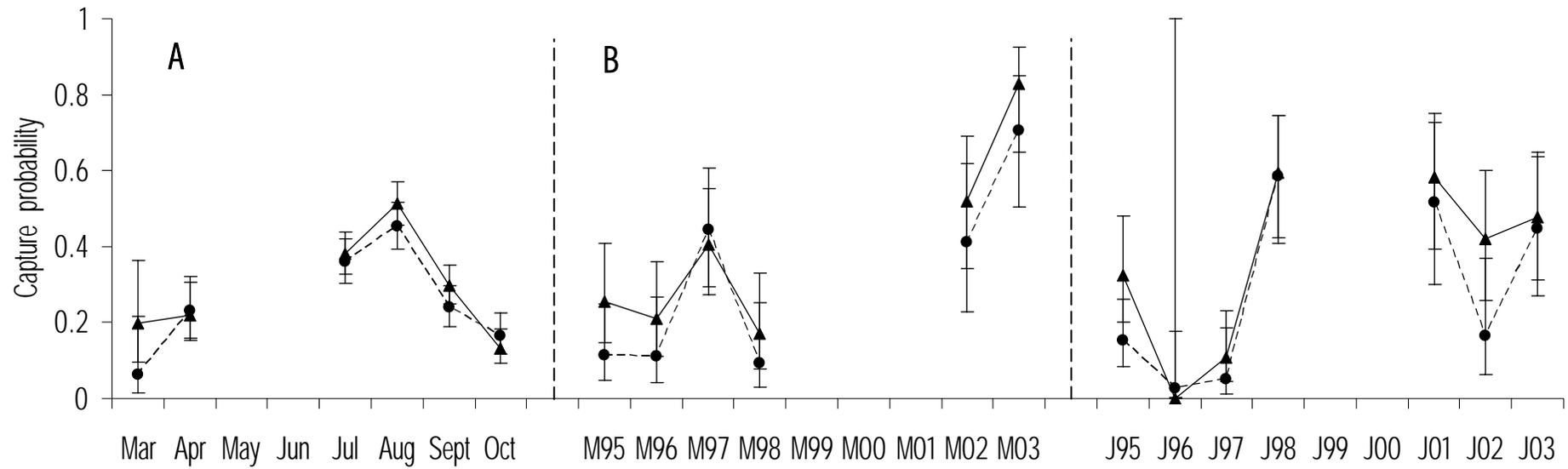


Figure 4.14 - Capture probabilities for known females (circles and dashed line) and males and animals of unknown gender (triangles and solid line), for Model 1F (Table 5) and 1U (Table 7), respectively. May and June are identified by their first capital letter (M or J) and the year (95 and following years)

4.3.3 Fecundity rate and calf survival rates

All individuals recognised and photographed as newborn calves (See Chapter 2) are listed in Table 4.10.

Table 4.10 - Date of birth of all photographed newborns born to poorly marked and well-marked adult females, including non-residents, between 1995 and 2003.

Presumed mother ID	Date of birth		Presumed mother ID	Date of birth	
	Month	Year		Month	Year
GRI	April	1995	VED	August	1998
EMI	July	1995	DOC	April	2000
IVA	July	1995	BAD	August	2000
SEX	July	1996	LUC	August	2000
SUS	July	1996	M0020	August	2000
VIV	July	1996	QUI	July	2001
NIN	July	1997	NAT	August	2001
SLA	July	1997	SAE	July	2002
SUS	August	1997	SON	July	2002
DEB	April	1998	M0208	August	2002
MIR	June	1998	M0227	October	2002
SEX	July	1998	MIR	May	2003

The resulting monthly distribution of births revealed a peak in mid-summer (when there was the highest effort), with some evidence for an additional peak in spring when 3 calves were seen in only 12 surveys (Fig. 4.15).

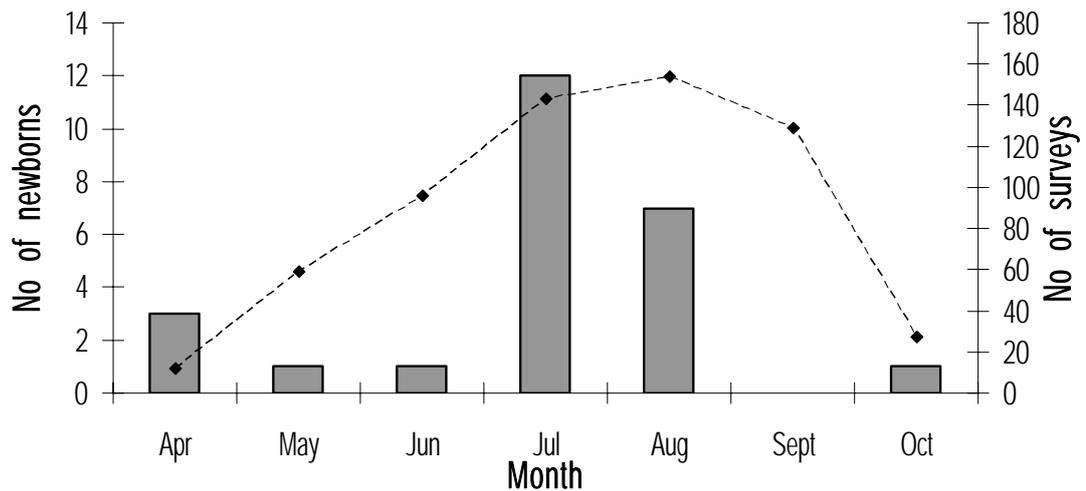


Figure 4.15 – Number of newborn calves born to all identified mothers (histogram) and number of photo-identification surveys (diamonds and dashed line) in each month of the study

Capture histories from 24 well-marked and 4 poorly-marked mothers and their 49 calves - chosen on the basis that their mothers were seen in at least six different years – were used to estimate fecundity rates and apparent survival rates of bottlenose dolphins in their 1st, 2nd, 3rd and 4th years (Table 4.10). There were 10 cases of animals seen as presumed yearlings, to which the year of birth was assigned as the previous year. The effective year of birth of five calves (identified with a * in Table 4.11) was obtained from Bearzi *et al.* (1997).

At least eight females were believed to be primiparous, because they were known to be resident from the beginning of this study or even earlier (dataset 1990-1994, see Bearzi *et al.* 1997) but had not previously been seen with a calf. Six of these animals lost their calves within the first year (Table 4.11).

Table 4.11 - Corrected capture histories of females seen in at least 6 years and their calves. Capture histories of females are highlighted in grey. Numbers beside name codes refer to the actual or assigned year of birth. Notations: PM = poorly-marked, WM = well-marked, and UM = unmarked; ○ = < 1 year old, ● = 1-3 years old, □ = 3-5 years old, ■ = immature adult; * year of birth from Bearzi *et al.* (1997)

Marking type	Sex	Code	1995	1996	1997	1998	1999	2000	2001	2002	2003
WM	♀	Ali	1	1	1	1			1	1	1
WM		Ali94	●	□	■	■			■	■	■
UM		Ali98				○					
UM		Ali02						○	●	●	
WM	♀	Bad	1	1		1	1	1	1	1	1
UM	♂	Bad94	●	●		□					
UM		Bad00						○	●	●	□
PM	♀	Ben	1		1	1		1		1	1
UM		Ben94	●		□						
UM		Ben98				○		●		□	■
WM	♀	Ber	1	1	1	1		1	1	1	1
UM		Ber97			○	●		□			
WM	♀	Bia	1	1	1	1	1	1		1	1
UM		Bia98				○	●	●		□	■
WM	♀	Cel	1	1	1	1	1	1			1
UM		Cel95	○	●	●						
UM		Cel98				○	●	●			
WM	♀	Dan	■	1	1	1	1	1	1	1	1
UM		Dan97			○	●	●	□	□		
WM	♀	Deb	1	1		1	1	1	1	1	1
UM		Deb95	○	●							
UM		Deb00						○	●	●	□
WM	♀	Doc	■		1	1	1	1	1	1	1
UM		Doc98				○					

Table 4.11 - (Continued). Corrected capture histories of a selection of mothers and their calves

Marking type	Sex	Code	1995	1996	1997	1998	1999	2000	2001	2002	2003
WM	♀	Emi	1		1	1	1	1	1	1	1
UM		Emi95	○		●	□					
UM		Emi00						○	●	●	□
WM	♀	Fede	1	1	1	1	1	1			
UM		Fede94*									
UM		Fede97			○	●	●	□			
WM	♀	Gib	1	1	1	1	1	1	1	1	1
UM		Gib95	○	●	●	□	■				
WM	♀	Gri	1	1	1	1		1	1	1	1
UM		Gri95	○	●	●	□		■			
UM		Gri02								○	●
WM	♀	Iva	1		1	1	1	1	1	1	1
UM		Iva95	○		●	□					
UM		Iva01							○	●	●
WM	♀	Lea		1		1	1	1	1	1	1
UM		Lea99					○				
WM	♀	Luc	■	■	1	1	1	1		1	
UM		Luc98				○					
UM		Luc00						○			
PM	♀	Mau	1		1	1	1	1	1	1	1
WM		Mau93*	●		□						
UM		Mau98				○	●	●			
WM	♀	Mel	1		1	1		1	1		1
UM		Mel97			○	●					
WM	♀	Mir	1	1	1	1	1	1			1
WM		Mir92*	□	□	■	■	■	■	■	■	
UM		Mir98				○	●	●			
UM		Mir03									○

Table 4.11 - (Continued). Corrected capture histories of a selection of mothers and their calves

Marking type	Sex	Code	1995	1996	1997	1998	1999	2000	2001	2002	2003
WM	♀	Qui	1		1	1	1	1	1	1	1
UM		Qui_02							○	●	●
WM	♀	Qui1	■			■	■	1	1	1	1
UM		Qui1_02							○	●	●
WM	♀	Rai	1	1	1	1		1	1	1	1
UM		Rai92*									
UM		Rai97			○	●					
WM	♀	Sci	1	1	1	1	1	1	1	1	1
UM		Sci92*	□								
UM		Sci97			○	●	●	●			
PM		Sci01							○	●	●
WM	♀	Sla	■	1	1	1	1	1	1	1	
UM		Sla97			○						
PM	♀	Sus	1	1	1	1	1	1	1	1	1
UM		Sus96		○							
UM		Sus97			○	●	●	□			
UM		Sus02								○	●
WM	♀	Tab	■	1	1	1	1		1	1	1
UM		Tab97			○						
WM	♀	Tac	■	■	1	1	1		1	1	1
UM		Tac98				○					
PM	♀	Ved		■	1	1	1	1		1	1
UM		Ved98				○					

Table 4.12 - Life-table of calves from 28 well-marked females present in the study area since the 1st year fo study (two from the 2nd year); a_x = number of animals surviving at the beginning of age x ; l_x = proportion of the original cohort surviving at the beginning of age x ; d_x =proportion of animals dying between age x and $x+1$; q_x = age specific mortality rate. Note: the number of animals in age classes marked with * may be biased downwards because calves may separate from their mothers at these ages

Age class (x)	a_x	l_x	d_x	q_x
Age 0	38	1.00	0.18	0.18
Age 1	31	0.82	0.13	0.16
Age 2	26	0.68	0.24	0.35
Age 3*	17	0.45	0.24	0.53
Age 4*	8	0.21	0.13	0.63
Age 5*	3	0.08	-	-

A life table of calves from females seen since the beginning of the study (two from the second year) is presented in Table 4.12.

The mean annual number of newborn calves to these females was 4.2 (n=9; SE=1.2). The observed number of females increased from 19 to 25 over the study period (Fig. 4.16), whereas the number of calves born each year declined, it was high and highly variable during the early years (1995-1999: mean=5.4, SE=1.9, range=1-10) and lower and less variable in the later years (2000-2003: mean=2.8, SE=0.8, range=1-4) (Fig. 4.17).

The annual fecundity rate for the study females varied between 0.05 and 0.37, with a mean of 0.171 (n=9, SE=0.046) (Fig. 4.17). Although there was some evidence of a decline over time this was not statistically significant ($R^2 = 0.2805$; $p>0.05$).

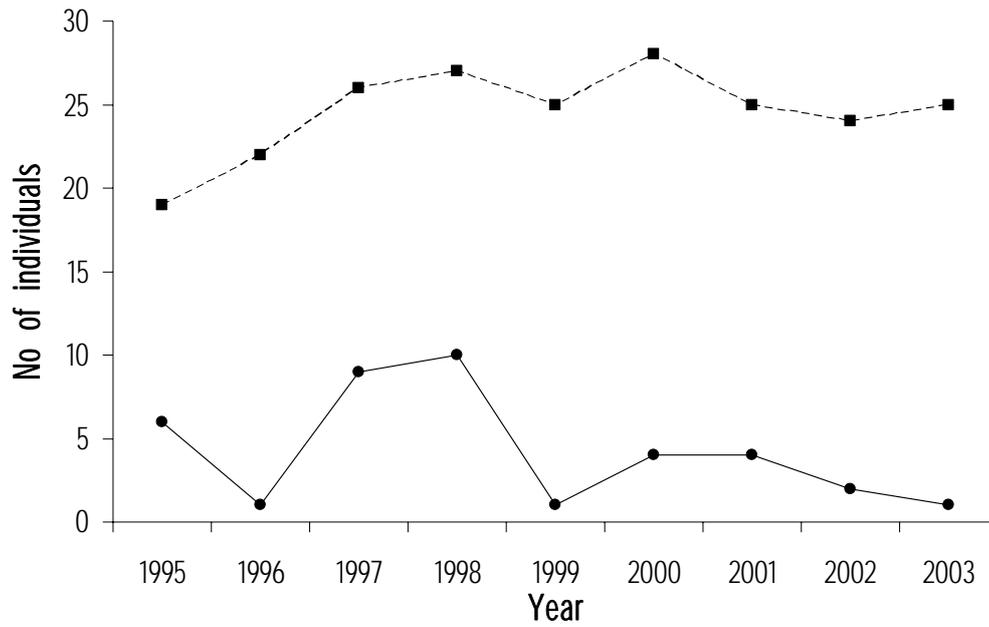


Figure 4.16 - Annual number of known mature females (squares and dotted line) and newborns (circles and solid line) in the study population

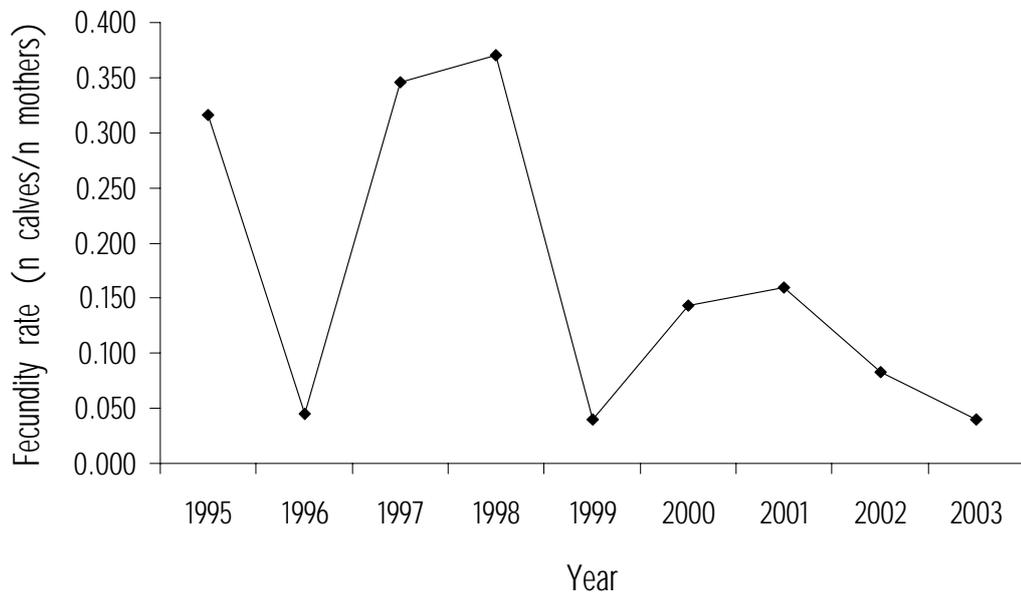


Figure 4.17 - Annual fecundity rate (number of newborn calves per mature females)

4.3.4 Calf survival

The analyses to estimate calf survival showed that a model with constant survival for calves aged 1-3 and aged 4-5 and capture probability varying over years had the most support from the data (Table 4.13). The second best model included calf survival estimates for each age during the first five years and capture probability varying over years.

Table 4.13 - Model fits to the calf dataset. ϕ , p are survival and capture parameters, respectively. Key: (t) or (age) means time- or age-dependent, (·) means constant.

Model	AICc	Δ AICc	AICc weight	No. parameters	Deviance
1C $\phi(\cdot)$ (age1-3) $\phi(\cdot)$ (age \geq 4) $p(t)$	198.86	0.00	0.546	6	94.00
2C $\phi(\text{age } 1)$ $\phi(\text{age } 2)$ $\phi(\text{age } 3)$ $\phi(\text{age } \geq 4)$ $p(t)$	200.84	1.98	0.203	7	93.75
3C $\phi(\text{age } 1)$ $\phi(\text{age } 2)$ $\phi(\text{age } 3)$ $\phi(\text{age } 4)$ $\phi(\text{age } \geq 5)$ $p(t)$	201.10	2.24	0.178	8	91.75

All other models with capture probability either constant or varying by age had Δ AICc > 22.

Table 4.14 - Estimates of survival with standard errors (SE) and 95% confidence intervals (95% CIs) obtained for the best models for calves of selected mothers subsets. Key: ϕ =apparent survival. Note: age classes marked with * are potentially biased.

Model 1C				
Parameter	Estimate	SE	CV	Upper CI
ϕ at Age 1-3	0.838	0.036	0.043	0.753 - 0.897
ϕ at Age \geq 4*	0.618	0.079	0.128	0.457 - 0.757
Model 2C				
Parameter	Estimate	SE	CV	Upper CI
ϕ at Age 1	0.771	0.063	0.081	0.625 - 0.872
ϕ at Age 2	0.970	0.070	0.054	0.235 - 1.000
ϕ at Age \geq 3	0.686	0.059	0.108	0.560 - 0.790

Capture probabilities for Model 1C varied over years between 0.61 (SE=0.13; 95% CI 0.35-0.83) and 0.88 (SE=0.11; 95% CI 0.49-0.98). Capture probabilities for Model 2C varied over years between 0.61 (SE=0.13; 95% CI 0.35-0.82) and 0.85 (SE=0.13; 95% CI 0.44-0.98). Overall, based on the result of these analyses a newborn calf had between 16 and 31% probability of weaning, based on a minimum weaning age of 3 years (Table 4.14). However, the 31% mortality must be biased high because the survival at age ≥ 3 includes ages 4 and 5 apparent mortalities. A comparison between the results obtained in Model 2C and those shown in the calf life-table (Table 4.12) highlights a big difference for the Age 2 estimated mortality at 3% (Table 4.14) vs. 16%.

4.4 DISCUSSION

The information presented in this study is important for ecological and conservation reasons. Results highlighted a rather interesting population dynamic which has an intrinsic ecological value and important management implications. These results are used in the following chapters as a basis for population viability and sensitivity analyses which will inform conservation efforts.

4.4.1 Exploratory analysis

The increase in the number of animals in the poorly-marked category after 1999 (Fig. 4.6) could possibly be explained by pulses of “recruitment” of young animals getting their first natural marks, rather than a continuous process. However, this time series is not long enough to investigate this further.

The discovery curve for all identifiable individuals (Fig. 4.7) did not approach an asymptote indicating that analyses based on both poorly and well-marked animals over the entire period (1995-2003) would have been problematic. This shape could be the result of “recruitment” of dolphins from the unmarked to the poorly-marked categories. Another reason to exclude poorly-marked animals from the mark-recapture analysis was that they have a higher probability of mark loss or mark change than well marked animals, and their recognition is more subject to photo-quality and the experience of the photographer (see Chapter 2).

4.4.2 Survival rates

First and foremost, the Kvarnerić adult bottlenose dolphins showed rather low rates of apparent survival. These are the lowest values mark-recapture estimates for any cetacean population, with the exception of one study on blue whales and one on sperm whales (Table 4.1). However, these two studies were focused on species or populations which had been intensively exploited by whaling (Calambokidis and Barlow 2004, Evans and Hindell 2004). As expected for large mammals, adult survival was fairly constant over time (Fowler 1981). No reason can be found to explain the 1999 survival estimate, which was significantly lower than any other. This year had the lowest effort but changes in effort should be accounted for by the estimates of capture probability, not the estimates of survival (see for example, Bradford *et al.* 2006). This variation could be a result of environmental stochasticity (Akçakaya 2000); however, based on the available information, it is not possible to identify any specific cause (e.g. weather, prey availability, etc.). The most precise estimate of survival was 0.914 (CV=0.032) based on pooled data from 2002 and 2003. These estimates of adult survival are significantly lower than the lowest found for the Sado estuary (Portugal) bottlenose dolphin population ($\phi=0.961$, SE=0.012; Gaspar

2003) and the one calculated for the Moray Firth population ($\phi=0.942$, $SE=0.048$; Sanders-Reed *et al.* 1999). The Moray Firth population is now known to have a wide range, with dolphins travelling up to 200 km away from the main study area (Wilson *et al.* 2004). However, a re-analysis (Philip Hammond *pers. comm.*) of these data ruled out a possible underestimation of survival rate caused by not considering temporary or permanent emigration. The only available estimate of a similar or lower survival rate for free-ranging bottlenose dolphins is one based on strandings of the Indian/Banana River population in Florida ($\phi=0.920$, Hersh *et al.* 1990; $\phi=0.902$, Stolen and Barlow 2003). Similar values were obtained for bottlenose dolphins in captivity, even though the survival of captive animals is usually considered to be lower than in the wild (DeMaster and Drevenack 1988, Small and DeMaster 1995). In both these cases, caution should be exercised because of the methods used, the related assumptions (life-tables) and the peculiarity of the study cases.

As temporary emigration of Kvarnerić bottlenose dolphins was modelled and permanent emigration of transient animals seems to be a minor issue in our dataset, our results should not be affected by these two phenomena. Given the gregarious nature of bottlenose dolphins (Wells and Scott, 1990), the length of this study (nine years) and the relatively small study area (about 1000 km²), the low apparent survival rate could be the consequence of a shift of the use of the study area by bottlenose dolphins. The other option is that it is the result of specific environmental and ecological factors (for example, prey abundance and distribution, level of anthropogenic pressure, habitat degradation). Cetacean populations, as with those of other marine mammal species, are regulated through density-dependent changes in reproductive and survival rates (see Fowler 1981, 1984 for a review). In species with highly structured societies (for example, killer whales and sperm whales) these

changes can be associated with food resources, or loss of a member of the pod (Best 1980, Bigg 1982).

Apparent survival rates of known reproductive females varied between 0.842 (CV=0.081) in 1999 and 0.989 (CV=0.020) in 2002-2003. On average, females showed a higher survival than male dolphins and those of unknown gender. Lower survival rates for males compared to females are not unusual in mammal species (Testa and Siniff 1987, Oleisiuk *et al.* 1990, Langtimm *et al.* 2004; Coulson *et al.* 2004) including bottlenose dolphins (Scott *et al.* 1990, Fernandez and Hohn 1998, Stolen and Barlow 2003). These differences are likely reflecting different life history tactics (Alcock 1989). However, it has been suggested that it may be a consequence of the fact that male dolphins accumulate toxic burdens with age (e.g. Weisbrod *et al.* 2001), whereas females transfer up to 67-70% of that burden to their first offspring during lactation (Cockcroft *et al.* 1989, Corsolini *et al.* 1995). This process has the potential to increase their survival, while strongly affecting that of their first offspring. However, the role of contaminants in the survival of dolphins has not been yet clarified (Aguilar and Raga 1993, Ross *et al.* 2000, Ross 2002). In the case of Kvarnerić bottlenose dolphins, whether this reflects a real difference in mortality rates or different ranging patterns and social organisation is difficult to infer without extending the research to both adjacent and more distant sites. Adriatic bottlenose dolphins have high levels of pollutants, especially PCBs, with males carrying about 67% higher level of PCBs than females (Corsolini *et al.* 1995). Such concentrations are higher than those found in animals showing reproductive failure and physiological impairment (Corsolini *et al.* 1995). This could partially explain the high mortality rate found for animals of unknown gender (mainly males and partially immature females) in this study, and the fact that most primiparous mothers lost their calves. Adult

survival has a high impact on the population dynamics of many marine mammals, including bottlenose dolphins (Eberhardt and Siniff 1977, Eberhardt 1985, Gaspar 2003, Runge *et al.* 2004); considerable attention should therefore be given to the mitigation of threats for that age class.

4.4.3 Temporary emigration

The Kvarnerić bottlenose dolphin population showed a 8-30% rate of non-random temporary emigration, with 15-71% probability of remaining unavailable outside the study area. Some of the values estimated for the non-random temporary emigration are close to those found for a typical migratory species showing a high site fidelity to feeding and breeding grounds like the grey whale (Bradford *et al.* 2006). A high site fidelity coupled to a high probability of remaining unavailable to capture implies a specific pattern of movements and likely the use of a wider area by this local bottlenose dolphin population. Despite the uncertainty in estimates, differences in type and rates of temporary emigration rates seem to exist between known females and animals of unknown gender, because a slightly lower temporary emigration rate for females was seen in all models. Females seem to be consistently more inclined to return (see values of ψ' in Table 4.7 and 4.9) and use the study area. These results are characteristic of a geographically open population and may suggest higher dispersal behaviour by males and non-reproductive females. In other words, males and non-reproductive females could be characterised by a stronger nomadic behaviour in relation to the study area, in contrast to the higher fidelity displayed by reproductive females. However, in general this local population seems to be characterised by a high fluidity, in terms of use of the study area.

4.4.4 Fecundity rate and inter-calving interval

The decreasing trend in fecundity rate (Fig. 4.17) cannot be attributed to reproductive senescence as there is no evidence that this occurs in bottlenose dolphins, although there is evidence for this in other Odontocete species, such as pilot and killer whales (Martin and Rothery 1993, Olesiuk *et al.* 1990), probably reflecting their matrilineal social system (McAuliffe and Whitehead 2005). If the selection of mothers used in this study represented almost the entire pool of mature females, the combination of two factors – the limited window given by the duration of the study and a calving interval of about six years - could partially confound a real long-term trend. Interestingly, this more stable decreasing trend was observed after five years of severe fluctuations (Fig. 4.17). Variations in birth rates have been linked to density-dependence phenomena in a number of Odontocetes species, such as spotted dolphin (*Stenella attenuata*), striped dolphin (*Stenella coeruleoalba*), spinner dolphin (*Stenella longirostris*), killer and sperm whale (Fowler 1984). It is possible to speculate about reasons for the observed changes in vital parameters observed during the study period. However, given the length of the study and the limited amount of environmental data for this area, such speculations can only represent a spur to identify more powerful and rigorous tools that may help us to define the true extent of anthropogenic effects at the population level.

The first year calf mortality obtained for offspring of resident mothers was found to be very high (about 23%). Even this could be an underestimate, for several reasons.

Newborn calves are difficult to photograph and identify, as they are generally hidden by the adults, unmarked and breathe more quickly (Grellier 2000, Grellier *et al.* 2003). In the Kvarnerić, younger mothers tend to travel in bigger groups and are known to be more difficult to approach, making photo-identification more difficult. It is, therefore,

recognised that a number of newborns may die before being first photographed (Wells and Scott 1990).

Concerning the life-table for age class 0 and 1, survival rates were consistent with those found for the Indian River Lagoon (Florida) population (Stolen and Barlow 2003); whereas in the following age classes, survival was markedly lower. The age specific mortality rate was very similar for calves of less than one year but higher in all other age classes; mortality of animals in age class 1 was lower than that for age classes 0 and age 2 in both populations.

Differences in the Kvarnerić bottlenose dolphin fecundity and calf survival rates compared to those for the Sado estuary population (Gaspar 2003) could reflect substantial differences in population dynamics between the two populations. The Sado population is small, geographically closed, with a low fecundity rate and consequently a high inter-birth interval; the Kvarnerić population is larger, experiences emigration episodes and is characterised by a higher fecundity rate.

Juvenile survival in mammals is typically lower and more variable than adult survival, and is thought to be more sensitive to environmental variations (Eberhardt 1977, Benton and Grant 1999, Gaillard *et al.* 1998, Portier *et al.* 1998). Variability in non-adult survival can play an important role in determining short-term population fluctuations and trends (Eberhardt and Siniff 1977, Gaillard *et al.* 1998, Coulson *et al.* 2004).

4.4.5 Capture probabilities

Capture probability was consistently higher in summer. This was probably due to the better weather conditions and higher research effort.

A substantial decrease in capture probability was found between May and June during the last biennium (Fig. 4.13 B). Capture probabilities in these two months are particularly interesting as they may reflect reactions by bottlenose dolphins to the sudden seasonal increase in numbers of boats in the archipelago. Perhaps the largest change in the last biennium was the construction of a marine petrol station in Nerezine (Fig. 3.14), which certainly affected the traffic around the southern edge of Cres Island. This area largely overlaps the main route connecting Mali Lošinj to Rab harbour (Fig. 3.14). This change occurred at the same time as a marked change of the use of the area highlighted during the last triennium of this study in relation to recreational boating activities (see Chapter 3). This suggests the attainment of a tolerance threshold to a certain type of human activity in the area by bottlenose dolphins.

4.4.6 Data and analysis caveats

From the annual and monthly encounter rate (encounters per survey day) (Fig. 4.2 and 4.3), we can infer that the probability of encountering a group of bottlenose dolphins during the study period was highly variable. This suggests that, although annual effort should not affect estimates, monthly effort may. In this case, the obvious linear correlation between effort and number of encounters and the distribution of the data about the regression line, suggests that weather conditions play a strong role in a successful research season. The only exception was June, with a significantly lower encounter rate than other summer months. This could be related to the start of the tourist season, which coincides with a sudden increase in boat traffic within the archipelago (Island Development Centre 1997, Harbour Master Zoran Tomić, pers. comm.). The correlation between effort and number of encounters also suggests an overall equal inter-monthly probability to sight a group within the study area. Capture

probabilities could have been influenced indirectly by environmental factors affecting our research effort and directly by anthropogenic activities within years, but not necessarily annually.

Only apparent survival could be estimated, because it is confounded with emigration and mark loss. Permanent emigration seems to be unlikely according to the fission-fusion society characterising this species (Mann and Smuts 1999). Applying a robust design, it was possible to account for temporary emigration. During the entire study, mark loss probably happened in the case of one individual that lost half of its dorsal fin; however, this was one of the individuals identified on the west side of the island and its capture history was not included in these analyses. Given the high frequency of annual photo-identification sampling, it is considered very unlikely that well-marked bottlenose dolphins were misclassified. It can therefore be assumed that apparent survival rate closely approximates true survival rate for well-marked bottlenose dolphins from Kvarnerić.

The danger of over-fitting the data with an over-parameterised model was minimised where possible by reducing the number of capture probability parameters, when this was allowed by the distribution of data.

The increased survey frequency during the summer months, when the birth rate and capture probability were higher, together with the fact that analysed mothers and calves were the most resident, can rule out any bias caused by misidentification. Although calves were always categorised as unmarked with respect to long-lasting marks, they were in many cases recognisable within, and sometimes between, research seasons due to shorter term scratches (Wilson *et al.* 1999b, Grellier *et al.* 2003).

There is nothing to suggest that the selected mothers behaved differently from other mothers within research seasons. The selection of only 28 mothers with a high degree of site fidelity avoided issues associated with heterogeneous use of the study area by individuals. This sample was chosen to produce an average estimate of fecundity and calving rate, and a reliable average estimate of survival in the first three years of calves' lives. Representativeness in term of age classes was guaranteed by the fact that both well- and poorly-marked mothers were included, a good proportion of these (at least 29%) were primiparous. The annual mean number of births and mean fecundity rate are underestimated, because some newborn calves must have been missed, but they do provide valuable information on minimum values for the entire population.

**CHAPTER 5: TRENDS IN KVARNERIĆ BOTTLENOSE
DOLPHIN ABUNDANCE**

5.1 INTRODUCTION

Reliable estimates of population size and density are often, or ideally should be, the foundation of ecological theory and wildlife management (Smallwood and Schonewald 1998, Thompson *et al.* 1998, Evans and Hammond 2004). This kind of information is particularly important for small marine mammal populations, especially if their habitat is strongly affected seasonally by anthropogenic activities, such as tourism and fisheries, which could induce additional mortality (D'Agrosa *et al.* 2000, King and Heinen 2004). Abundance estimates are the basis for calculating man-induced rates of mortality, and are required to evaluate whether these are sustainable or not and are a prerequisite of any robust management scheme (IWC 1994, Wade 1998, Reeves *et al.* 2003). For example, a number of different *fora* have recommended or set by-catch limits for small cetaceans. ICES proposed a value of 1.7% of population size, based on the work of an IWC/ASCOBANS joint Working Group on North Atlantic harbour porpoises (DEFRA 2003), as a basis until better estimates of population growth can be estimated. Such a limit, however, could be prohibitive for severely depleted populations or those that are highly structured in sub-populations. Therefore, if the uncertainty about the population structure is high, a precautionary approach should favour values well below 1.7% (ICES 2001). The Scientific Committee of the International Whaling Commission (IWC) has agreed that small cetacean by-catch should not exceed half of the maximum growth rate of a population (Perrin *et al.* 1994). In the case of harbour porpoise (*Phocoena phocoena*) the IWC adopted a value of 1% “*as a reasonable and precautionary level beyond which to be concerned about the sustainability of anthropogenic removals*”. Under the U.S. Marine Mammal Protection Act (MMPA) the Potential Biological Removal (PBR) has been defined as the maximum number of animals that may be removed by human

pressures from a marine mammal population (or sub-population), whilst still allowing that population to reach or maintain its Optimum Sustainable Population (OSP).

However, estimation of population size is not an easy task, especially for cetaceans (Hammond *et al.* 1990; Evans and Hammond 2004), which represent one of the most elusive orders of wildlife. Estimates of cetacean population size are traditionally based on distance sampling methods, such as line transect surveys (Buckland *et al.* 1993), or capture-recapture methods³ based on photo-identification surveys⁴ (Hammond 1990a, Hammond *et al.* 1990). The latter is usually the best option for the bottlenose dolphin, which possesses good natural markings, is often coastal and tends to live in relatively small local populations. Mark-recapture methods are often used to estimate the size of bottlenose dolphin populations, typically using models for closed populations taking into account temporal and individual heterogeneity (Williams *et al.* 1993; Wilson *et al.* 1999b, Ingram 2000, Read *et al.* 2003a, Mackelworth *et al.* 2002a).

The principle relationship underlying all mark-recapture models is as follows: if in a given population a sample (n_1) of individuals is marked or photo-identified and the population is re-sampled after a period that allows complete mixing, then the ratio of the number of marked individuals (m_2) to the size of the second sample (n_2) should be equal to the ratio of the total number of marked animals in the total population size (N). Thus,

$$\frac{m_2}{n_2} = \frac{n_1}{N} \qquad \text{Equation 5.1}$$

Rearranging equation 5.1 gives the two-sample Lincoln-Petersen estimator (Petersen 1896, Lincoln 1930):

³ This is synonymous with mark-recapture and capture-release.

⁴ In mark-recapture studies on cetaceans “mark” or “capture” means “photographically captured”.

$$\hat{N} = \frac{n_1 n_2}{m_2}$$

Equation 5.2

General assumptions of mark-recapture methods are presented in the Introduction of Chapter 4 (Paragraph 4.1). In closed population models a major assumption is that no births, deaths, immigration, or emigration occur for the population under study.

The Lincoln-Petersen estimator is basic but it (or its variants) has been used to estimate abundance in pairs of years for a number of species (Baker *et al.* 1985, Grellier and Wilson 2003, Stevick *et al.* 2003, Calambokidis and Barlow 2004, Larsen and Hammond 2004). When studies allow for multiple sampling occasions, a number of more complex estimators can be applied to obtain a time series, and models for open populations can also be applied (Otis *et al.* 1978, Hammond 1986, Hammond *et al.* 1990, Chao 2001, Chao *et al.* 2001, Amstrup *et al.* 2005).

The advent of more powerful computers that can carry out complex calculations and of specific software, such as MARK (White and Burnham 1999) and CAPTURE (Rexstad and Burnham 1991), has made it possible for biologists to apply more complex models in a user friendly environment. In distance sampling methods, the average number of animals in a specified area is estimated at the time of the survey(s). In contrast, capture-recapture methods estimate the number of individual animals using the study area over the period of the study. Thus, while distance sampling methods typically require a representative sample of the area surveyed, capture-recapture methods require a representative sample of individual animals using the area.

Conventional capture-recapture methods produce negatively biased population estimates in the presence of heterogeneity of capture probabilities, a condition that is

inherent in cetacean populations (Hammond 1986, Hammond 1990b, Hammond *et al.* 1990, Thompson *et al.* 1998, Amstrup *et al.* 2005). Heterogeneity can be caused by differences among members of the same population due to behaviour, including preferred group size, movement patterns, or habitat use, and variation in the quality of markings patterns used to assign identifications. Closed population models can deal with heterogeneity due to unequal capture probabilities because robust estimators have been developed to obtain unbiased population estimates (Otis *et al.* 1978). However, estimates of variance are typically larger and therefore larger sample sizes are required in terms of marked animals and recapture rates to achieve the same precision. The balance is thus between bias and precision. The use of “non-heterogeneity” estimators has the potential of creating a “biased but apparently precise” scenario (White *et al.* 1982) that is highly undesirable if the estimates are to be used for management.

In this chapter, photo-identification data collected during nine years of sampling (see Chapter 4) of this well-marked population of bottlenose dolphins are used to estimate population size and evaluate potential trends. Estimates from three different closed population models are compared.

As for any other long-lived species, studying the abundance of bottlenose dolphins requires monitoring activities that need significant investments in terms of time and funds. A power analysis was performed to examine the power of the current monitoring regime to detect trends and to explore potential alternative options (Taylor and Gerrodette 1993, Wilson *et al.* 1999b).

5.2 MATERIAL AND METHODS

5.2.1 Sampling regime

Photo-identification data were collected between 1995 and 2003 as described in Chapter 4. Data were grouped into months to constitute 50 sampling occasions in total, varying between 4 and 7 occasions per year.

5.2.2 Abundance estimates and trends

In this study only models considering temporal variation in capture probability (M_t), heterogeneity of capture probability (M_h) and the combination of these two factors (M_{th}) have been applied. Model M_t can differ in the type of estimator used (Darroch or Chao estimators; Darroch 1958, Chao 1989). The Darroch model assumes that all animals in the population have an equal probability of capture at any one time, but that the probability of capture can vary among sampling occasions. If equal sampling effort is used on each sampling occasion then this model may be appropriate. The Chao estimator (1989) does not calculate population size through the standard maximum likelihood (ML) estimator. The model accounting for individual variation in capture probability (M_h) considers the option of unequal capture probabilities between animals, which may arise from differences in sex, age, social dominance, differences in individual activity, etc. Program CAPTURE estimates population size using the Chao (1989) or Jackknife estimators. When probabilities of capture are small, the Chao estimator performs much better than the Jackknife. The combination of models M_t and M_h gives the model M_{th} , which is often considered the most appropriate model to avoid negative bias in estimates of population size (Chao *et al.* 2001), particularly for cetacean populations that are characterised by temporal and individual unequal capture probabilities (Wilson *et al.* 1999, Read *et al.* 2003).

Huggins' model (see Huggins 1989, 1991 for full details on estimators) is essentially an M_{thb} estimator for closed populations (where M_b is an estimator that allows for behavioural heterogeneity in which animals have a different capture probability after first capture), where all types of heterogeneity are taken into account by using covariates (Chao *et al.* 2001), such as effort and residency (Bradford *et al.* 2006). Without the use of covariates it becomes a simple M_t estimator for closed populations. This approach is equivalent to the Horvitz-Thompson sampling design (see Horvitz and Thompson (1952) for full details), where animals have unequal probability of being included in the sample. In this analysis, covariates were not used, so the Huggins model did not take account of heterogeneity.

Models accounting for behavioural heterogeneity were not considered because it is generally agreed that photo-identification of cetaceans should not lead to changes in capture probabilities, due to such things as trap-happy and trap-shy responses (Wilson *et al.* 1999b; Read *et al.* 2003a).

Abundance estimates were calculated using program CAPTURE run from MARK 4.2 (<http://www.cnr.colostate.edu/~gwhite/mark/>), except for Huggins' model which is included in the Robust Design option of MARK.

The best model was selected through chi-squared tests of explained deviance. Population estimates produced from the Huggins model and the most appropriate annual M_t or M_{th} model allowed a test of the sensitivity of population estimates to assumptions about heterogeneity in the sampled population.

Photo-identification and matching procedures and age-class definition are described in Chapters 2 and 4.

The shape of the discovery curve of well-marked individuals (Fig. 4.7 Chapter 4) showed that the assumption of demographic closure within secondary sampling occasions (i.e. within years) should be valid, and that in any potential bias would be less than 1%. This population is known to have a very high prevalence of injuries, nicks, scars and tooth marks (Wilson *et al.* 1999a). By using only well-marked individuals it was assumed that any bias arising from mark loss and failure to recognise marks would tend towards zero. Temporal variability and individual heterogeneity of capture probabilities was taken into account by the M_{th} model using the Chao estimator. Individual heterogeneity due to geographical preferences was partially accounted for by discarding all encounters on the western side of Cres and Lošinj islands (see Chapter 4 for more details).

Abundance estimates were then corrected for the proportion of well marked dolphins, $\hat{\theta}$, after Wilson *et al.* (1999) as follows:

$$\hat{\theta} = \frac{1}{E} \sum_{i=1}^E \left(\frac{l_i}{n_i} \right) \quad \text{Equation 5.3}$$

where E is the number of encounters, l_i is the number of animals with long-lasting marks in encounter i , and n_i is the total number of animals in encounter i .

$$\hat{N}_{tot} = \frac{\hat{N}}{\hat{\theta}} \quad \text{Equation 5.4}$$

where \hat{N} is the mark-recapture estimate of the number of animals with long-lasting marks and \hat{N}_{tot} is the estimated total population size. The variance was estimated using the delta method as:

$$\text{var}(\hat{N}_{tot}) = \hat{N}_{tot}^2 \left(\frac{\text{var}(\hat{N})}{\hat{n}^2} + \frac{1 - \hat{\theta}}{n\hat{\theta}} \right) \quad \text{Equation 5.5}$$

As in Wilson *et al.* (1999), the estimated proportion of animals with long-lasting marks in the population was calculated based only on encounters where all individuals in the school were determined, regardless of their degree of markings (including calves).

Log-normal confidence intervals for the total population size were calculated as follows (Thompson *et al.* 1998):

$$MNA + \frac{\hat{N}_{tot} - MNA}{C_l}, \quad MNA + (\hat{N}_{tot} - MNA) \times C_l \quad \text{Equation 5.6}$$

where

$$C_l = \exp \left(1.96 \sqrt{\ln \left[1 + \frac{\text{Var}(\hat{N}_{tot})}{(\hat{N}_{tot} - MNA)^2} \right]} \right) \quad \text{Equation 5.7}$$

MNA is the minimum number of animals known to be alive in the population, that is the number of animals that were captured, and $\hat{N}_{tot} - MNA$ is the number of animals that were never captured.

5.2.3 Observed mortality

In order to ascertain any potential impact on this population of bottlenose dolphins from non-natural mortality, data on standings were explored in relation to the annual abundance estimates.

An annual rate of observed mortality was calculated as the annual number of recovered bottlenose dolphin carcasses in the Kvarnerić divided by the estimated

population size (\hat{N}_{tot}). Annual rates of observed mortality were compared to annual estimated mortality rates (see Chapter 4).

5.2.4 Power analysis and future monitoring

In order to assess the optimal length of the time series of abundance estimates and their precision, and their ability to detect significant population changes, a power analysis was carried out (Wilson *et al.* 1999b, Evans and Hammond 2004).

Gerrodette's (1987) general inequality formula was used to investigate the power of a series of population estimates to detect changes:

$$r^2 n^3 \geq 12CV^2 \left(\frac{z_\alpha}{2} + \frac{z_\beta}{2} \right)^2 \quad \text{Equation 5.7}$$

where r is the annual rate of population change, n is the number of survey years, CV is the coefficient of variation of estimated total population size, $\frac{z_\alpha}{2}$ and $\frac{z_\beta}{2}$ are the one-tailed probabilities of making a Type I error and Type II error, respectively. When setting the probability of making a Type I or II error at 0.05 and 0.10, respectively, Equation 5.7 can be simplified as follows:

$$r^2 n^3 \geq 156CV^2 \quad \text{Equation 5.8}$$

$$r^2 n^3 \geq 103CV^2 \quad \text{Equation 5.9}$$

As the CV of annual estimates varied according to the sampling effort, different values of CV were used to explore the number of successful photo-identification surveys needed to detect a trend of a given magnitude.

5.3 RESULTS

5.3.1 Sampling regime

Details of the annual mark-recapture sampling, including the proportion of well-marked bottlenose dolphins estimated annually and their variances are presented in Table 5.1. During the nine years of study the total monthly sampling occasions varied between four and seven. In any one year, between 41 and 78 well-marked dolphins were photographed. On average, 55% of the whole pool of well-marked dolphins was captured annually (range 31% - 71%). Seventy-four percent of dolphins were captured in three or more different years, 47% in more than 5 years, 28% in more than 7 years and 5% in all years. The estimated annual proportion of well-marked animals ranged between 0.56 and 0.78, with a higher variability in 1999 and 2002 (Table 5.1). The total mean of monthly successful photo-identification surveys (those with at least one encounter) was 6.3 (SE=0.5).

Table 5.1 - Summary of the mark-recapture sampling details for the Kvarnerić study area, including proportions of well-marked bottlenose dolphins estimated annually (θ)

Primary periods (Year)	Months	Mean of successful monthly surveys (SE)	Animals captured	θ (SE)
1995	7	6.7 (1.2)	78	0.72 (0.04)
1996	6	4.8 (1.4)	66	0.76 (0.03)
1997	6	8.2 (1.9)	76	0.78 (0.04)
1998	7	5.0 (1.2)	65	0.58 (0.04)
1999	4	5.8 (2.6)	41	0.61 (0.08)
2000	4	8.8 (2.0)	58	0.56 (0.06)
2001	5	5.8 (1.3)	47	0.72 (0.06)
2002	6	4.3 (1.0)	50	0.70 (0.08)
2003	5	8.6 (0.8)	57	0.62 (0.04)

5.3.2 Abundance estimates and trends

The estimated proportion of unmarked dolphins recorded each year was highly variable (Fig. 5.1).

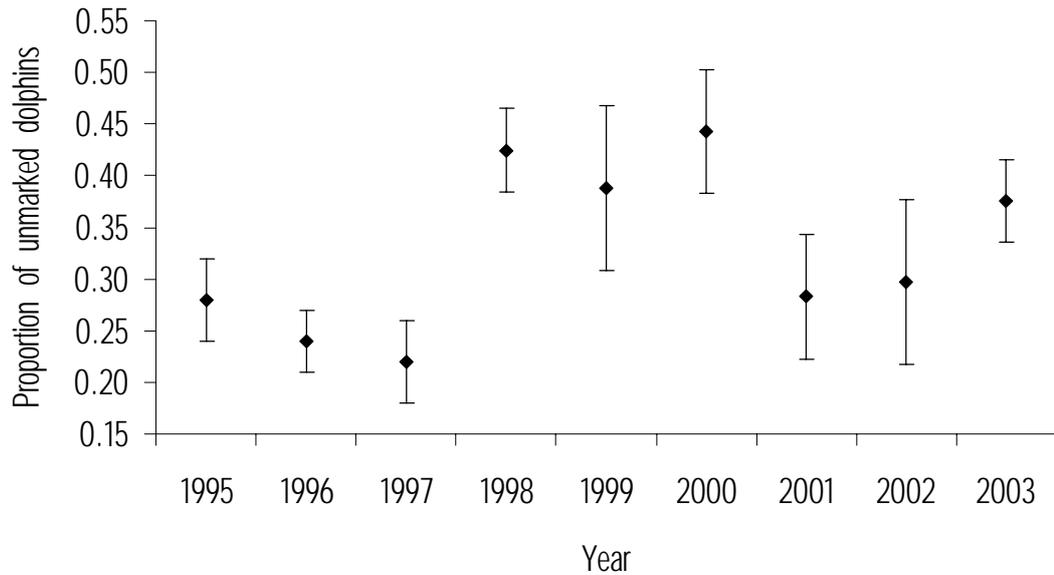


Figure 5.1 – The proportion of unmarked dolphins ($1-\hat{\theta}$) recorded in the Kvarnerić study area each. Vertical bars represent \pm one Standard Error

Table 5.2 shows all the abundance estimates of well-marked bottlenose dolphins in Kvarnerić obtained from the MARK and CAPTURE analyses. The Huggins model did not account for heterogeneity, because no covariates were used in the robust design and capture probabilities were modelled based only on secondary sampling occasions, as described in Chapter 4.

Table 5.2 - Abundance estimates of well-marked bottlenose dolphins in the Kvarnerić study area from mark-recapture analyses for the Huggins closed captures (Huggins 1989), M_{th} (Chao et al. 1992) and M_t (Darroch 1958) models

Year	Huggins for closed captures			M_{th} with Chao estimator			Best models (chi-square test of deviance)			
	\hat{N}	SE	95% CI	\hat{N}	SE	95% CI	\hat{N}	SE	95% CI	Model and estimator
1995	86	3.19	82-95	121	15.59	100-163	121	15.59	100-163	M_{th} Chao
1996	79	4.22	73-90	117	20.67	90-175	78	5.24	72-93	M_t Darroch
1997	85	3.39	80-94	95	7.69	85-116	79	2.06	78-86	M_t Darroch
1998	69	2.20	66-76	75	5.64	69-92	75	5.64	69-92	M_{th} Chao
1999	51	3.72	46-62	48	7.26	43-78	45	2.71	43-54	M_t Darroch
2000	71	4.17	65-82	66	5.93	61-87	65	3.70	61-76	M_t Darroch
2001	52	2.42	49-59	75	13.61	59-116	75	13.61	59-116	M_{th} Chao
2002	54	2.23	51-61	58	5.68	53-77	58	5.68	53-77	M_{th} Chao
2003	59	1.41	57-64	64	4.55	60-79	64	4.55	60-79	M_{th} Chao

As expected, models accounting for heterogeneity gave overall higher abundance estimates, except in 1999 and 2000 when slightly higher estimates were given by the Huggins estimator (Table 5.2 and Fig. 5.2). In 1996, 1997, 1999 and 2000 the chi-square test on explained deviance indicated that the M_t model was most appropriate. All annual estimates from different models seemed consistent in terms of overall trend, with a larger difference for some estimates during the first two years of the study (Fig. 5.2).

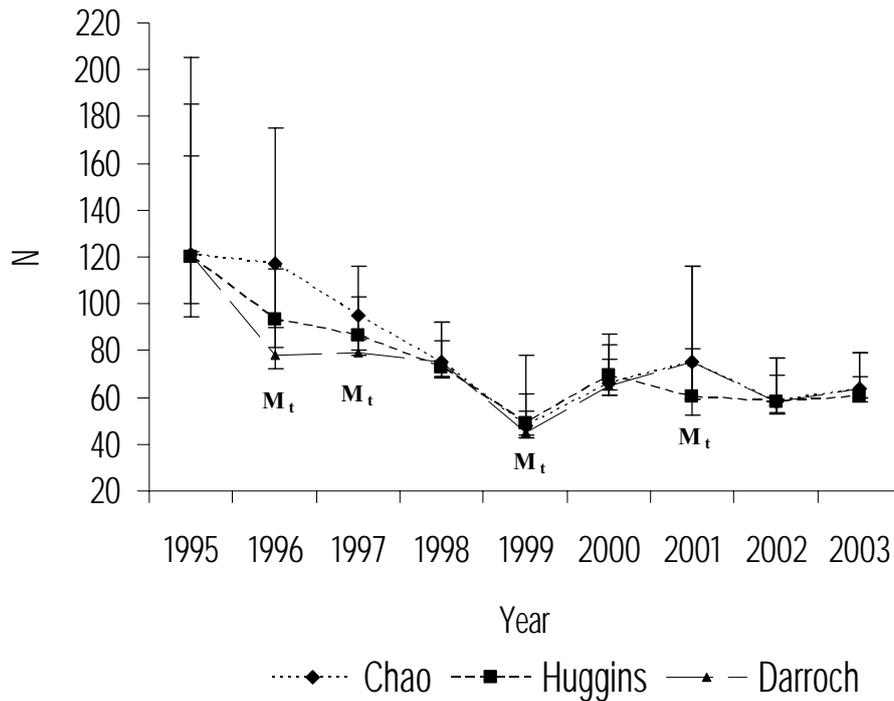


Figure 5.2 - Abundance estimates of well-marked bottlenose dolphins in the Kvarnerić study area. Vertical bars indicate the 95% CI: M_{th} model-Chao estimator (circles), M_t or M_{th} models with Darroch and Chao estimators (triangles) and Huggins model for closed populations (squares)

Estimates obtained from the different models showed a high degree of consistency; however, because the M_{th} (Chao) model takes best account of heterogeneity, the M_{th} estimates were selected for all years.

Estimates of the total abundance of Kvarnerić bottlenose dolphins (population size adjusted for the proportion of unmarked dolphins) are summarised in Table 5.3.

At the beginning of the study the Kvarnerić bottlenose dolphin population was estimated at 168 animals (CV=0.14, 95% CI 132-229) but by 2003 the populations had decreased to around one hundred dolphins (CV=0.10, 95% CI 86-127). This represents a decrease of 39% in the point estimate over nine years. The observed decreasing trend between 1995 and 2003 was significant ($t=-3.461$, $p=0.011$) (Fig. 5.3).

Table 5.3 - Estimates of the size of the total population of bottlenose dolphins (\hat{N}_{tot}) in the Kvarnerić study area from mark-recapture analyses: M_{th} model (Chao *et al.* 1992). \hat{N} = abundance estimate of the well-marked population, θ = proportion of well-marked individuals

Year	\hat{N}	θ	\hat{N}_{tot}	SE	CV	95% CI
1995	121	0.72	168	24.0	0.14	132-229
1996	117	0.76	154	28.9	0.19	113-231
1997	95	0.78	122	12.1	0.10	103-152
1998	75	0.58	130	14.3	0.11	108-165
1999	48	0.61	78	14.4	0.18	59-119
2000	66	0.56	119	15.6	0.13	95-157
2001	75	0.72	105	20.4	0.20	76-160
2002	58	0.70	82	9.8	0.12	68-108
2003	64	0.62	102	10.2	0.10	86-127

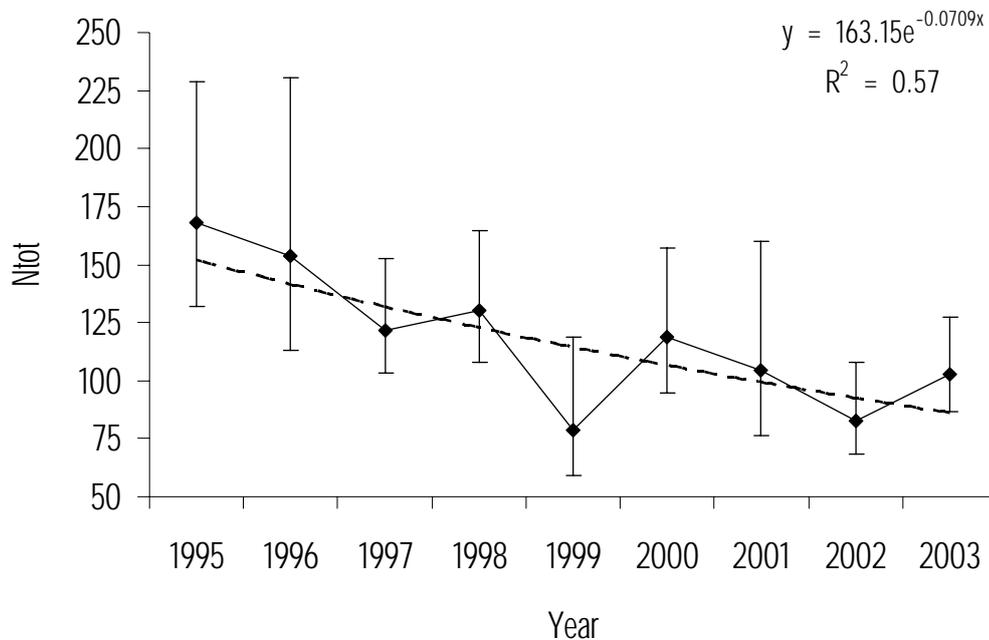


Figure 5.3 - Abundance estimates of total population of bottlenose dolphins in the Kvarnerić study area obtained with M_{th} model-Chao estimator. Vertical bars represent the 95%CI, the dotted line is the fitted exponential regression line

An exponential curve was fitted to the population estimates (Fig. 5.3), to provide an estimate of the intrinsic rate of change for this population of -0.07 (n=8, SE=0.03).

5.3.3 Observed mortality

The annual observed mortality rate was 2.56% (SE=0.60, n=9). On average, one dead adult (mean=0.89, SD=0.78) and one dead sub-adult (mean=0.89, SD=0.78) was found in each year the study (Table 5.4).

Table 5.4 – Summary of the available data on bottlenose dolphins carcasses recovered within the study area

	95	96	97	98	99	00	01	02	03
Deaths attribute to human-induced mortality			1(♀)			1(♀)	1(♀)		1(♂)
‘Natural’ mortality	1	1	4		1	2	3	3	4
<i>Total</i>	<i>1</i>	<i>1</i>	<i>5</i>	<i>0</i>	<i>1</i>	<i>3</i>	<i>4</i>	<i>3</i>	<i>5</i>
<i>Sex</i>									
♀	1		3			1	1	1	1
♂			2			1	1	1	2
Unknown		1			1	1			2
<i>Age classes</i>									
Adult			3		1	2	1	1	1
Sub-Adult	1	1	2				1	1	2

Since 2000, about one animal per year was incidentally caught in fishing gear or died because of illegal use of dynamite for fishing purposes. The relationship between the apparent annual non-calf mortality estimated in different years (see Chapter 4) and the observed mortality is shown in Figure 5.4. No concurrence was found. Observed

mortality rates were from 2 to 7 times lower than equivalent estimated annual mortality rates; the median being 2.1 (mean=3.5, SE=0.9, n=6).

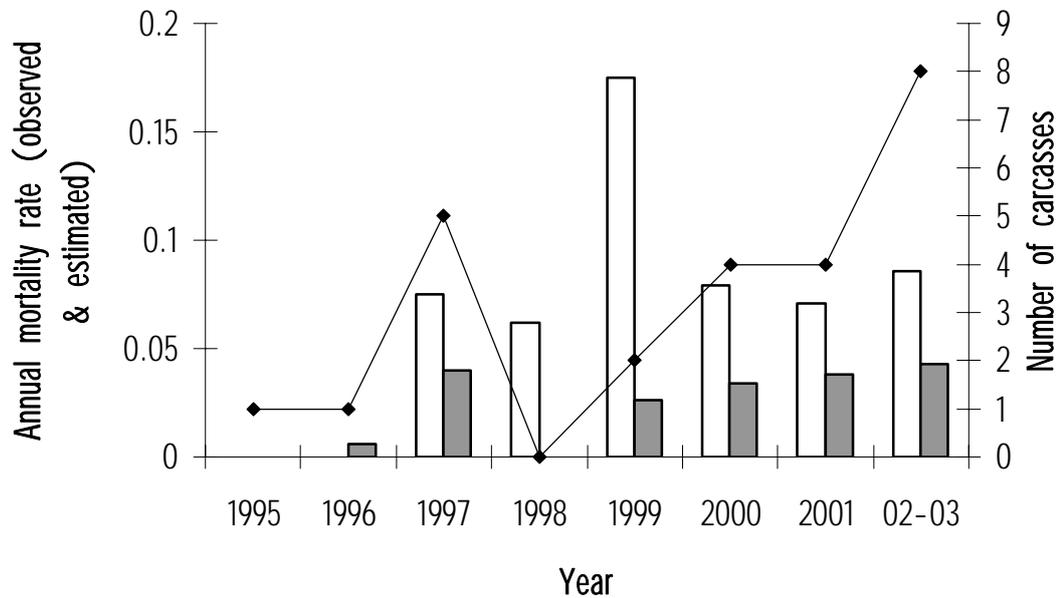


Figure 5.4 - Annual number of recovered bottlenose dolphins' carcasses in Kvarnerić (line), estimated (open bars) and observed (solid bars) annual adult mortality rates. See also Table 6.6. Observed mortality is given by the number of carcasses recovered each year divided by the estimated size of the Kvarnerić population

5.3.4 Power analysis and future monitoring

Based on three different CVs and two different probability levels for Type I error and Type II error (0.05 and 0.10), equations 5.7 and 5.8 were used to calculate how many years would be required to allow the detection of a positive or negative trend of a given magnitude (Fig. 5.5). Two of the CVs (0.10 and 0.20) incorporated the range obtained from the estimates in this study (Table 5.3, M_{th} model with Chao estimator). A CV = 0.30 was chosen to represent a worst case situation.

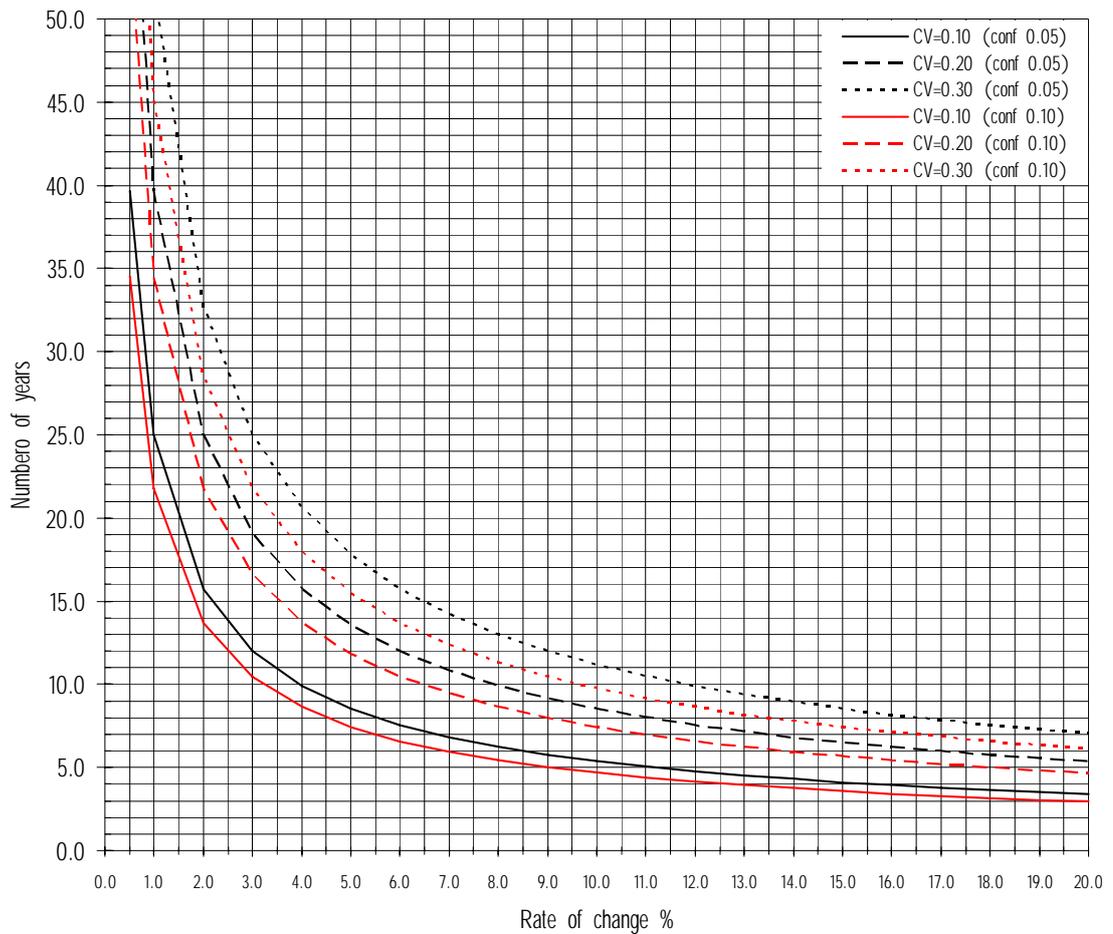


Figure 5.5 - Number of years required to detect a trend of a given magnitude for different levels of precision of the population estimate (CV=0.10, 0.20 and 0.30) with threshold probability level set to 0.05 and 0.10

In general, low rates of change can only be detected if more than 22-25 years of data are available. Only really long-term studies, at least 14-16 years and up to 34 depending on the CV and probability level, can ensure the detection of rates of change of 2% or lower (Fig. 5.5). Only very dramatic changes (18-20%) could be detected in a relatively short period of time (3-8 years).

By lowering the probability level, the number of years needed to detect a trend decreased (Fig. 5.5); however the overall difference was small (only one or two years).

On the other hand, an increase in the level of precision had a stronger effect. For example, a rate of change of 3.5% can be detected in 11, 17 or 23 years according to CVs of 10, 15 and 20, respectively.

In this study, the lowest CV (0.10), was recorded in 1997 and 2003. In 1997 there were six months of monitoring with an average of eight successful surveys (with at least one encounter) per month, in 2003 there were five months of monitoring with an average of nine successful surveys per month. The most unfavourable years (CV of about 0.20) were characterised by six months of monitoring with an average of five successful surveys per month, and five months of monitoring with an average of six successful surveys per month, respectively. Monitoring regimes characterised by these amounts of survey effort would allow rates of change between 20% and 5 % to be detected in about 3 and 14 years, respectively.

5.4 DISCUSSION

5.4.1 Annual abundance estimates and trends

This study presents the first reliable data on trends in abundance of a local population of bottlenose dolphins within the Mediterranean Sea.

Based on the 2003 abundance estimate, the Kvarnerić bottlenose dolphin population (as defined in Chapter 1) contains around 100 animals. This greatly increases its extinction probability, regardless of which type of management approach may be applied (precautionary vs. traditional) (Thompson *et al.* 2000). In addition, the decrease of about 39% in abundance detected over the study period should act as a

warning to policy makers that urgent and strong protection measures are required at a local, and probably at a National, level.

The estimates of population size provided here - between 103 and 165 individuals - are very similar to published estimates for bottlenose dolphin populations in the Moray Firth, Scotland (129 animals, 95% CI 110-174; Wilson *et al.* 1999b), and in the Shannon Estuary, Ireland (113 animals, 95% C.I. 94-161; Ingram 2000). Furthermore, the southern population of North Carolina, USA displays some similarity (141 animals, 95% CI 112-200 individuals; Read *et al.* 2003a). If the Kvarnerić population is near carrying capacity and the study area is large enough to cover the population main range, one could hypothesise that such estimates define the maximum number of animals such ecosystems can sustain. Environmental changes (natural or anthropogenic) would have a direct effect on population size (Gerrodette 1987, Gerrodette and DeMaster 1990, Kasuya 1991, Sibly and Hone 2002, Branch *et al.* 2004), either by increasing mortality or inducing a shift in habitat use. However, in long-lived, adaptable and highly social marine mammals, such as bottlenose dolphins, (Wells 1991, Mann and Smuts 1999, Connor *et al.* 2000), sudden and direct reactions to environmental changes would not be expected. In fact, bottlenose dolphins populations, as other cetaceans and marine mammal species in general, can still remain stable or even decrease when their population sizes are well below the carrying capacity (Loughlin *et al.* 1987, Fay *et al.* 1989, Pitcher 1990, Gerber *et al.* 2000, Waring *et al.* 2002, Estes *et al.* 2005). In this population, the reasons for the observed decline should probably be sought in pathological or toxicological stressors that have a long-term impact on survival and reproduction (Corsolini *et al.* 1995, Waring *et al.* 2002, Soulé *et al.* 2003, Wells *et al.* 2005).

The precise causes of the observed decline in the Kvarnerić study population are unclear. However, based on the available information, it seems reasonable to suspect that changes in nautical tourism may have displaced animals from the core of the study area (see Chapter 3). The disturbance caused by the increasing number of speedboats using this area in summer could have affected the patterns of temporary or permanent emigration in this bottlenose dolphin population. Mammals living in a highly structured society tend to move to adjacent areas if they are disturbed (Alcock 1989). This hypothesis could readily be tested by enlarging the geographic scope of the current study.

Overexploitation of marine resources after the end of the war (i.e. since 1996) could also be a contributing factor. Nevertheless, it is not possible to confirm that the regional carrying capacity of the study area has decreased recently. The bottlenose dolphin is known to be generalist in terms of diet (Barros and Odell 1990), but it seems to be selective when given the opportunity (Corkeron *et al.* 1990). In the Mediterranean region bottlenose dolphins appear to have a preference for the European hake (*Merluccius merluccius*) (Blanco *et al.*, 2001; Orsi Relini *et al.*, 1994; Voliani and Volpi, 1990). The Adriatic animals are no exception to this rule, being “generalist” but “opportunistically selective” (Mikovic *et al.* 1998, Stewart 2004). In addition, the diet of Kvarnerić animals appears to have shifted in recent years from demersal to pelagic fish species (Stewart 2004), which are now more abundant.

Another cause of the observed decline could be illegal direct takes, collisions or bycatch. Based on the limited number of recorded strandings, human-induced mortality has increased from below 1% to 1-2% of the population, which may not be sustainable. This concern is heightened by the fact that observed annual mortality was about half of the total estimated mortality (see Chapter 4 and Fig. 5.4) in each year,

even though the number of recovered carcasses almost certainly underestimates true levels of mortality.

Understanding whether the observed decline has a geographic basis (i.e. a consequence of emigration) or demographic one (increased mortality) is important. Based on the increasing seasonal displacement of dolphins from certain areas (see Chapter 3), the relatively stable adult survival rate (see Chapter 4), and apparent local declines of stocks of demersal fish species (Croatian Environmental Agency, http://baza.azo.hr/projekt_more/index.htm, first entered on 18 January 2005), emigration seems to represent the most likely future scenario. The dynamics of the Kvarnerić bottlenose dolphin population appear to be characterised by a high rate of temporary emigration (Chapter 4). This could explain the apparent inconsistency between the stable adult survival rate (Chapter 4) and the observed decline. Although this suggests that the observed decline is less worrying for the conservation of this species in the entire northern Adriatic Sea, the disappearance of a charismatic species that is attractive to tourists (Mackelworth 2006) could have serious consequences for the local ecosystem and the local economy.

Given the clear indication of a negative trend in abundance, an appropriate course of management action would, therefore 1) acknowledge that there is a risk that the local bottlenose dolphin population may disappear; 2) take temporary measures that could help to ease the current situation by mitigating or removing factors that may be responsible for displacement of dolphins (see Chapter 3); 3) augment the existing monitoring scheme to cover adjacent areas to the south and west of the Lošinj-Cres archipelago; 4) measure the success of the management actions against baseline data gathered before the actions were implemented. These simple steps would apply to any case with similar characteristics: a declining small population of an economically-

valuable, charismatic, K-selected species characterised by highly adaptive behavioural habits and where there is strong circumstantial evidence that human activity is having detrimental impacts.

5.4.2 Implications for local conservation of bottlenose dolphins

Reliable estimates of absolute abundance are essential to the conservation of bottlenose dolphins in the Adriatic Sea. The term “Kvarnerić population” or “local population” has been used here in a sense that is different to its common ecological use (See paragraph 1.1.4.2). It is closer to the IUCN definition (2003) in which “local population” is synonymous with Wells and Richmond’s (1995) “subpopulation”: a definable set of individuals that are not spatially isolated from other groups. The term “local population” implies that the species has a meta-population structure, which involves the extinction and recolonisation of suitable patches (Hanski and Gaggiotti 2004). At the international level, the observed a decrease in the size of a local population would be sufficient to propose that the Kvarnerić population should be given the IUCN listing Endangered (IUCN 2005) at a regional level under Criterion C2a(i) (a population of less than 250 mature individuals, currently declining). Even though IUCN Red List Categories and Criteria were originally developed for assessing the risks of global extinction, the concept has been extended for the purposes of regional conservation assessment (IUCN 2003). Within this framework, the concept of a “Kvarnerić bottlenose dolphin population” is entirely appropriate.

A precautionary approach and special protection measures have been proposed for two small populations of bottlenose dolphins living at the extremes of the species’ worldwide range, the Moray Firth (UK) population (Thompson *et al.* 2000) and the Doubtful Sound (New Zealand) population (Lusseau and Higham 2004), even though no significant trends in abundance have been detected. In the first case, precautionary

management was proposed based on a power analysis combined with a Population Viability Analysis, with emphasis being placed on the development of an integrated management body with strong links between decision-makers, scientists and all representatives of the relevant industrial activities (Thompson *et al.* 2000). In New Zealand, the creation of a marine sanctuary to mitigate the possibility of adverse impact of unregulated boating and dolphin-watching activities has been proposed, (Lusseau and Higham 2004).

Based on the findings in this thesis and a study of the socio-economic aspects of the implementation of the proposed Lošinj and Cres Marine Protected Area (Mackelworth 2006), the State Secretary of the Ministry of Culture of the Republic of Croatia, Dr. Jadran Antolovic, declared the establishment of the Lošinj Dolphin Reserve (Ministry of Culture, Republic of Croatia, UP/I-612-07/06-33/676, 532-08-02-1/5-06-1, July 26, 2006) on 6 August 2006. This area (Fig. 2.1) is now protected under the Croatian Law for Nature Protection (Official Gazette No. 162/03) as a “Special Zoological Reserve for bottlenose dolphins (*Tursiops truncatus*)” and, as such, is subject to the strictest type of protection regime. Initially, the area receives “preventive protection”, which inhibits the development of any new human activities, for a maximum of three years. This will allow the establishment of a management body and the preparation of a management plan for the permanent Reserve. After this period, the designation will become permanent through a Decree of the Government.

**CHAPTER 6: THE FUTURE VIABILITY OF THE
KVARNERIĆ BOTTLENOSE DOLPHIN POPULATION**

6.1 INTRODUCTION

Risk Assessment is a relatively recently developed methodology for associating threat exposure to biological populations. It was initially developed to assess risk for human populations associated with exposure to hazardous chemicals, essentially quantifying the probability that an undesirable outcome may occur (Harwood 2000). One of the most used Risk Assessment methodologies in conservation biology is Population Viability Analysis (PVA) for threatened or endangered species. PVA is a collection of models for evaluating threats faced by populations or species, through estimates of risk of extinction or decline and chances of recovery over a given period (Boyce 1992, Norton 1995, Beissinger and Westphal 1998). Currently available PVA models can run simulations integrating demographic data for simple or multiple populations with habitat quality and patchiness, rates of migration between sub-populations and genetic effects (Akçakaya 2000a, Akçakaya 2000b). They may also take into account demographic and environmental stochasticity by performing Monte Carlo simulations or from additional variance around mean vital rates (Harwood 2000, Beissinger and McCullough 2002, Morris and Doak 2002, Shaffer *et al.* 2002, Taylor *et al.* 2002).

PVA has been subject to strong criticism as a tool for estimating absolute values of growth or extinction risk; models often fail to take uncertainty fully into account, resulting in unreliable conclusions (Conroy *et al.* 1995, Coulson *et al.* 2001, Taylor *et al.* 2002). Certain PVA estimated parameters, such as extinction risk, can however be usefully applied to test different scenarios or management strategies. (Coulson *et al.* 2001).

Sensitivity analyses are a set of analytical methods based on simulations that facilitate the evaluation of how changes in life-history parameters can affect population dynamics (Martien *et al.* 1999, Akçakaya 2000b, Akçakaya and Sjögren-Gulve 2000,

Mills and Lindberg 2002). This is, therefore, a fundamental component of PVA, which allows the relative impact that changes of demographic parameters or environmental variations can exert on the resilience of wildlife populations to be explored, and the effect of different management approaches to be tested.

Sensitivity analysis can also provide a way to see how models respond to inaccuracies in their parameters, helping to determine which parameter requires careful estimation (Akçakaya 2000b, Akçakaya and Sjögren-Gulve 2000).

PVA has been applied to a variety of terrestrial mammal species (for example, Blackwell *et al.* 2001, Haydon *et al.* 2002) and marine mammal species, including Hector's dolphin (Martien *et al.* 1999, Slooten *et al.* 2000, Burkhart and Slooten 2003) and bottlenose dolphin populations (Sanders-Reed *et al.* 1999, Thompson *et al.* 2000, Gaspar 2003).

By combining Risk Assessment and decision analysis, an integrated methodology can be devised. The aim of this is to quantify uncertainty and create a management framework that can then be applied (Akçakaya and Sjögren-Gulve 2000, Harwood 2000).

Ecological theory predicts that K-selected species, characterised by long lives and 'slow' life histories, will be at greater risk than short-lived species with higher potential rates of increase (Heppel *et al.* 2000, Oli and Dobson 2003).

In this Chapter *ad hoc* PVA and sensitivity analyses, partially based on parameters estimated in previous Chapters, are undertaken to obtain a preliminary risk assessment for the Kvarnerić bottlenose dolphin population and to provide information that will allow the potential impact of different management options to be explored.

6.2 MATERIALS AND METHODS

6.2.1 PVA parameters

Population Viability Analysis is based on a set of population parameters characterising each species. Some of these values were available for the population of bottlenose dolphins in the Kvarnerić, specifically mortality rates (average, sex and age specific; Chapter 4), fecundity rates (Chapter 4), and initial population size (Chapter 5). Other parameters were extrapolated from other studies and indicative values were chosen (Table 6.1). Some parameters were common to all analyses.

Extinction probabilities were calculated based on one thousand simulations over a 100 year projection; probability of extinction was considered at 60 and 100 years. Sixty years was used as a measure of three generations in small odontocetes (see the Report of the IUCN-ACCOBAMS Workshop 2006) for applying these results to the IUCN criteria for red listing. Extinction was defined as only one sex surviving. The sex ratio at birth was assumed to be 1:1. The percentage of males in the breeding pool was arbitrarily set at 50%. The maximum breeding age was assumed to correspond to the maximum longevity, because in bottlenose dolphins there is no indication of reproductive senescence (Marsh and Kasuya 1986, Cockcroft and Ross 1989). The carrying capacity was arbitrarily set at 200 dolphins. Analyses were carried out in VORTEX (version 9.58, <http://www.vortex9.org/vortex.html>). No information was available on genetic effects for this population. No catastrophic events were used in these simulations.

Table 6.1 – Summary of reproductive parameters for the bottlenose dolphin. Values observed in different studies (OV) and values used in this PVA

Parameter	OV (yr)	For PVA (yr)	Source
Reproductive system		Polygynous	Wells <i>et al.</i> 1987, Connor <i>et al.</i> 1996
Female Age at maturity	5-12	10	Perrin & Reilly 1984; Cockcroft & Ross 1989; Bearzi <i>et al.</i> 1997; Kasuya <i>et al.</i> 1997; Reynolds <i>et al.</i> 2000
Male Age at maturity	8-14	11	Perrin & Reilly 1984; Cockcroft & Ross 1989; Kasuya <i>et al.</i> 1997; Reynolds <i>et al.</i> 2000
Longevity	35-50	50	Cockcroft & Ross 1989; Hohn <i>et al.</i> 1989; Fernandez & Hohn 1997; Kasuya <i>et al.</i> 1997; Reynolds <i>et al.</i> 2000; Stolen & Barlow 2003
Gestation time	1	1	Perrin & Reilly 1984; Schroeder 1990

Whenever possible, Demographic Stochasticity (DS; between year variation in the observed numbers of births and deaths that is the result of simple binomial variability with constant demographic rates) and Environmental Variability (EV; between year variations in demographic rates that are assumed to be the result of extrinsic environmental factors) were taken into account. Such variability was modelled as binomial and normal distributions, respectively. The standard deviation due to Environmental Variability (σ_{EV}) was calculated as follows:

$$\sigma_{EV} = \sqrt{\sigma_{EV}^2} = \sqrt{\sigma_{TOT}^2 - \bar{\sigma}_{DS}^2}$$

where σ_{TOT}^2 is the total variance across the data and $\bar{\sigma}_{DS}^2$ is the mean binomial sampling variance across individual rates.

Different scenarios were explored and sensitivity analyses carried out by varying some of the parameters. The potential sustainability of indirect takes (for example, animals by-caught or killed by other human activity) was explored by simulating removals.

A Base case PVA model was built using the survival values obtained from the analysis of the whole dataset (see Chapter 4). In this scenario there were no differences in mortality between sexes. The Sex-specific survival case model (SSS) was built using survival values obtained from the two sex-specific subsets of data (see Chapter 4). In general, the best year for reproduction was set as the best year for survival (see Table 4.11 for support). The Sex-specific best adult survival case model (SSBAS) was constructed using the best estimates for each age and sex category (see Chapter 4). The complete set of values input to program VORTEX for these scenarios is shown in Table 6.2.

6.2.2 Observed age and sex specific mortality

Data on observed mortality were stratified by age class, according to the definition given in Chapter 2, and sex. A specific distinction was made for natural and human-induced mortality, when the data allowed it.

Table 6.2 – Summary of input values to VORTEX for different scenarios and their Standard Deviation. Key: Sex-specific survival case model (SSS), Sex-specific survival case model with Environmental Variability (SSS-EV), Sex-specific best adult survival case model (SSBAS) and Sex-specific best adult survival case model with Environmental Variability (SSBAS-EV)

PVA models	Base case	SSS	SSS-EV	SSBAS	SSBAS-EV
Correlation of EV between reproduction and survival	No	No	Yes	No	Yes
% Fecundity rate (SD due to EV)	17	17	17.0 (11.2)	17	17 (11.2)
% Female Mortality rate Age 0 (SD due to EV)	18.7	18.0	18.0 (3.6)	18.7	18.7 (3.6)
% Female Mortality rate Age 1 (SD due to EV)	18.7	16.2	16.2 (3.6)	18.7	18.7 (3.6)
% Female Mortality rate Age 2 (SD due to EV)	18.7	16.3	16.3 (3.6)	18.7	18.7 (3.6)
% Female Mortality rate Age 3 (SD due to EV)	18.7	16.2	16.2 (3.6)	18.7	18.7 (3.6)
% Female Mortality rate Age ≥ 4 (SD due to EV)	8.6	6.9	6.9 (5.4)	1.1	1.1 (5.4)
% Male Mortality rate Age 0 (SD due to EV)	18.7	18.0	18.0 (3.6)	18.7	18.7 (3.6)
% Male Mortality rate Age 1 (SD due to EV)	18.7	16.2	16.2 (3.6)	18.7	18.7 (3.6)
% Male Mortality rate Age 2 (SD due to EV)	18.7	16.3	16.3 (3.6)	18.7	18.7 (3.6)
% Male Mortality rate Age 3 (SD due to EV)	18.7	16.2	16.2 (3.6)	18.7	18.7 (3.6)
% Male Mortality rate Age ≥ 4 (SD due to EV)	8.6	9.8	9.8 (1.9)	9.8	9.8 (5.4)

6.3 RESULTS

6.3.1 PVA results

Results of the Population Viability Analysis are summarised in Table 6.3. The Base case model predicted a population declining steeply at an average rate of 6-7% per year with a high risk of extinction (Fig. 6.1 A). The Sex-specific survival case model (SSS) showed a more positive scenario (Fig. 6.1 B) compared to the Base case model,

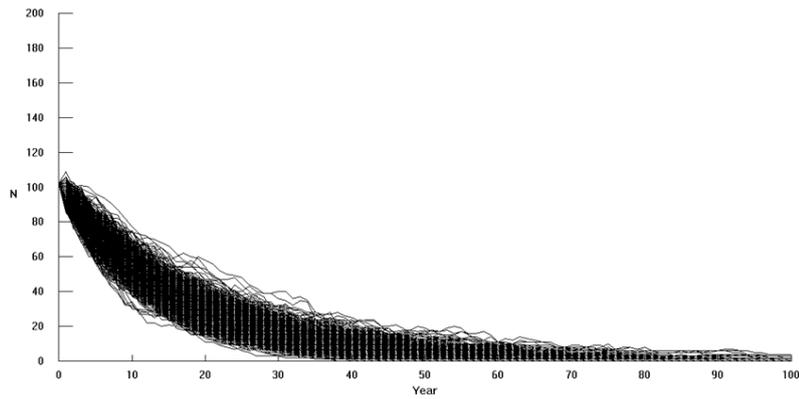
by decreasing the annual rate of decline to 4-5% and the risk of extinction to about 25-35%, but only in the short-term (60 years). Adding environmental variability in survival and reproductive rates to this model increased the extinction risk over 60 years, but not in the longer-term (100 years).

The very optimistic scenario described by the Sex-specific best adult survival case model (SSBAS) predicted a very slightly positive population growth rate and no risk of extinction over either 60 or 100 years (Fig. 6.1 C). Adding environmental variability to this model increased the extinction risk only very slightly.

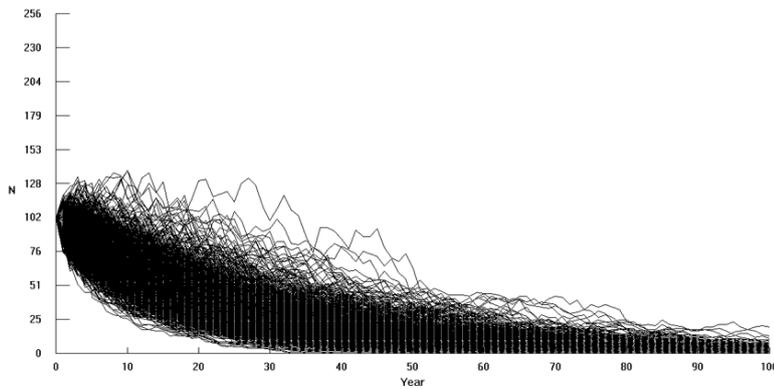
All simulations, apart from the Sex-specific best adult survival case model (SSBAS), predicted the mean size of all extant population sizes to be less than 10 after both 60 and 100 years.

All estimated stochastic population growth rates were highly variable (large standard deviations), reflecting the variability in the input data.

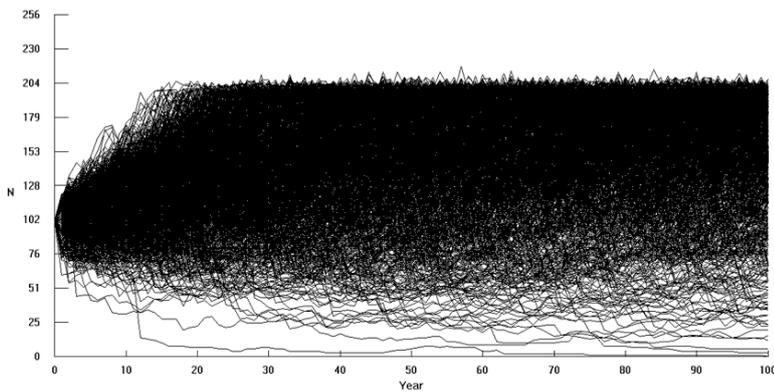
Final statistics: $r = -0.064$, $SD(r) = 0.114$, $PE = 1.00$, $N = 3$, $H = 56$



A



B



C

Figure 6.1 - Vortex simulations for the main three scenarios: (A) Base case, (B) Sex-specific survival case model with Environmental Variability (SSS-EV), and (C) Sex-specific best adult survival case model with Environmental Variability (SSBAS-EV)

Table 6.3 – Summary of the results of the Population Viability Analyses for various models: Sex-specific survival case model (SSS), Sex-specific survival case model with Environmental Variability (SSS-EV), Sex-specific best adult survival case model (SSBAS) and Sex-specific best adult survival case model with Environmental Variability (SSBAS-EV). Key: deterministic growth rate (det-r), stochastic growth rate (stoc-r), percentage risk of extinction in 60 years (% ext-risk 60) and in 100 years (% ext-risk 100), mean population size of surviving populations within 60 years (N-exta 60) and 100 years (N-exta 100)

Scenario	det-r	Stoc-r	% ext-risk 60	N-exta 60 (SD)	% ext-risk 100	N-exta 100 (SD)
Base case	-0.064	-0.065 (0.114)	70.6	4 (2)	99.7	3 (1)
SSS	-0.044	-0.048 (0.106)	25.1	8 (4)	93.4	4 (2)
SSS-EV correlation survival/reproduction	-0.044	-0.05 (0.128)	35.2	9 (6)	93.3	5 (2)
SSS no correlation survival/reproduction	-0.044	-0.05 (0.117)	34.9	9 (5)	94	5 (3)
SSBAS	0.004	0.003 (0.027)	0.0	128 (23)	0.0	146 (32)
SSBAS-EV correlation survival/reproduction	0.004	0.002 (0.086)	0.1	122 (50)	0.8	120 (53)

Sensitivity analyses run on the Sex-specific survival case model, including Environmental Variability (SSS-EV) with correlation between survival and reproduction, showed that variation in age at maturity or fecundity rate exerted little influence on the risk of extinction at 100 years but more on that at 60 years (Tables 6.4 and 6.5). Varying adult female mortality rate had strong effects on extinction risk. Decreasing adult female mortality increased the risk of extinction in the short (60 years) and long term (100 years). Moreover, a decrease of only 2% in mature female annual mortality rate (from the initial 6.9% to 4.9%), halved the extinction risk in the long term (100 years) and brought it well below 10% for the 60 year projection.

Table 6.4 – Summary of results of the sensitivity analyses on the basis of the Sex-specific survival case model with Environmental Variability (SSS-EV). Key: deterministic growth rate (det-r), stochastic growth rate (stoc-r), percentage risk of extinction in 60 years (% ext-risk 60) and in 100 years (% ext-risk 100), mean population size of surviving populations within 60 years (N-exta 60) and 100 years (N-exta 100)

Scenario	det-r	stoc-r	% ext-risk 60	N-exta 60 (SD)	% ext-risk 100	N-exta 100 (SD)
SSS-EV	-0.044	-0.05 (0.128)	35.2	9 (6)	93.3	5 (2)
<i>Reproductive parameters</i>						
♂ maturity at 10 years	-0.044	-0.049 (0.127)	32.0	9 (7)	92.2	4 (3)
♂ maturity at 12 years	-0.044	-0.049 (0.126)	31.4	10 (7)	93.5	5 (4)
♀ maturity at 9 years	-0.043	-0.048 (0.128)	29.0	10 (7)	90.7	5 (3)
♀ maturity at 11 years	-0.046	-0.05 (0.126)	36.2	9 (6)	95.1	6 (4)
Fecundity rate 16%	-0.047	-0.051 (0.129)	38.6	9 (6)	94.6	4 (3)
Fecundity rate 11%	-0.060	-0.064 (0.130)	68.9	5 (4)	99.4	3 (1)
<i>Adult female mortality rate decreasing in 1% steps, starting from 6.9% (SSS-EV model)</i>						
♀ mortality 5.9 %	-0.035	-0.042 (0.124)	19.8	14 (10)	79.7	7 (5)
♀ mortality 4.9 %	-0.026	-0.032 (0.116)	7.7	23 (16)	55.2	13 (10)
♀ mortality 3.9 %	-0.017	-0.022 (0.107)	1.9	37 (25)	27.1	25 (23)
♀ mortality 2.9 %	-0.008	-0.012 (0.096)	0.7	64 (38)	7.1	48 (38)
♀ mortality 1.9 %	0	-0.002 (0.091)	0.0	101 (50)	1.5	95 (53)
<i>Human-induced mortality</i>						
♀ 1 adult removal	-0.044	-0.096 (0.111)	100.0	0	100.0	0
♀ 1 sub-adult removal	-0.044	-0.072 (0.133)	87.9	4 (2)	100.0	0
♂ 1 adult removal	-0.044	-0.075 (0.104)	97.7	1 (1)	100.0	0
♂ 1 sub-adult removal	-0.044	-0.057 (0.126)	78.4	10 (6)	100.0	0

Table 6.5 – Relative changes in the input and output parameters. Key: deterministic growth rate (det-r), percentage risk of extinction in 60 years (% ext-risk 60) and in 100 years (% ext-risk 100), variation in the percentage risk of extinction in 60 years (% relative change ext-risk 60) and in 100 years (% relative change ext-risk 100) in relation to the Sex-specific survival case model with Environmental Variability (SSS-EV)

Scenario	% relative change in input parameter	Output parameters and relative variation					
		det-r	% det-r relative change	% ext-risk 60	% relative change ext-risk 60	% ext-risk 100	% relative change ext-risk 100
<i>Reproductive parameters</i>							
♂ maturity at 10 years	-0.09	-0.044	0.00	32	-0.09	92.2	-0.01
♂ maturity at 12 years	0.09	-0.044	0.00	31.4	-0.11	93.5	0.00
♀ maturity at 9 years	-0.10	-0.043	0.02	29	-0.18	90.7	-0.03
♀ maturity at 11 years	0.10	-0.046	-0.05	36.2	0.03	95.1	0.02
Fecundity rate 16 %	-0.06	-0.047	-0.07	38.6	0.10	94.6	0.01
Fecundity rate 11 %	-0.35	-0.06	-0.36	68.9	0.96	99.4	0.07
<i>Survival parameters</i>							
♀ mortality 5.9 %	-0.14	-0.035	0.20	19.8	-0.44	79.7	-0.15
♀ mortality 4.9 %	-0.29	-0.026	0.41	7.7	-0.78	55.2	-0.41
♀ mortality 3.9 %	-0.43	-0.017	0.61	1.9	-0.95	27.1	-0.71
♀ mortality 2.9 %	-0.58	-0.008	0.82	0.7	-0.98	7.1	-0.92
♀ mortality 1.9 %	-0.72	0	1.00	0	-1.00	1.5	-0.98
<i>Human-induced mortality</i>							
♀ 1 adult removal	-	-0.044	0.00	100	1.84	100	0.07
♀ 1 sub-adult removal	-	-0.044	0.00	87.9	1.50	100	0.07
♂ 1 adult removal	-	-0.044	0.00	97.7	1.78	100	0.07
♂ 1 sub-adult removal	-	-0.044	0.00	78.4	1.23	100	0.07

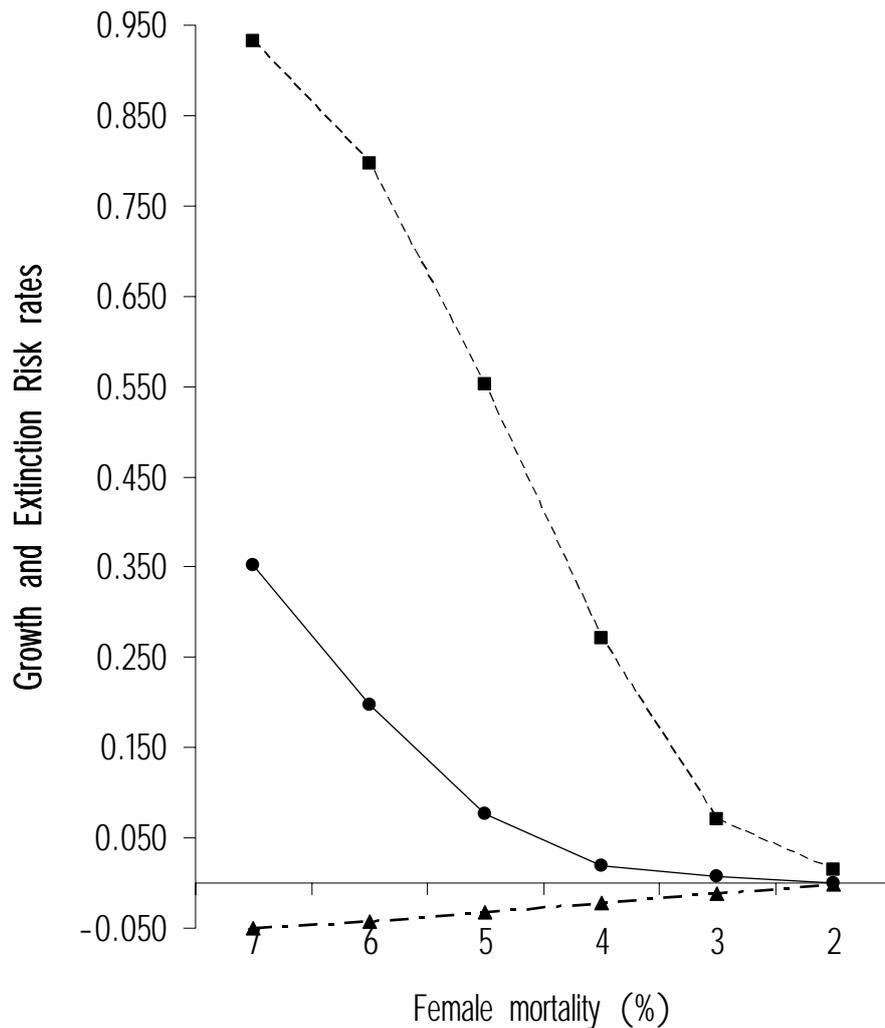


Figure 6.2 - Relationships between stochastic population growth rate (triangles joined by a dotted/dashed line), risk of extinction within 60 years (circles joined by a solid line) and 100 years (squares joined by a dashed line), and adult female mortality rate

To illustrate the effect on model output of the most sensitive parameter, relationships between adult female mortality rate and stochastic growth rate and risk of extinction at 60 and 100 years are shown in Figure 6.2. The population growth rate was predicted to become positive with adult female mortality lower than 2% per year (Fig. 6.2).

However, simulations that predicted negative growth rates ranging from -1.7% to 0% predicted levels of extinction risk of about 0-2% in 60 years and below 30% in 100 years (Fig. 6.2).

Any unnatural mortality of adult bottlenose dolphins had a very high impact in hastening the extinction of the population. As expected, deaths of immature males had less impact on population growth than deaths of reproductive animals and immature females.

6.3.2 Observed age- and sex- specific mortality

A total of 23 dead bottlenose dolphins were recovered within the Kvarnerić between 1995 and 2003. A summary of the available information on age and sex distribution is given in Table 5.4. Between 1997 and 2003, two deaths were strongly suspected to have been caused by dynamite fishing and two were accidentally by-caught adult animals. Three out of these four animals were females; one of which was a pregnant resident female (ID: “Boat” in 1997, see also Bearzi *et al.* 1997).

6.4 DISCUSSION

The overall outcomes of the sensitivity analyses were consistent with what would be expected for a K-selected species, and in particular for the bottlenose dolphin (Sanders-Reed *et al.* 1999, Gaspar 2003). Despite the fact that the absolute predictions should be considered with care (Ludwig 1999, Coulson *et al.* 2001, Beissinger and McCullough 2002, Morris and Doak 2002, Possingham *et al.* 2002), the extinction risk assessment and related frameworks, such as the IUCN red-listing procedure, are valuable (Colyvan *et al.* 1999, Brook *et al.* 2000, Beissinger and McCullough 2002, Morris and Doak 2002, Lamoreux *et al.* 2003). Therefore, the nature of the extinction risk projections over 60 years (approximately three generations) and the effect that a

single indirect take can have on the Kvarnerić population growth should be noted with serious concern.

According to Oli and Dobson (2003) the population dynamics of “slow” mammals, characterised by a ratio between fecundity and age at maturity lower than 0.15, are expected to be most sensitive to perturbations in survival parameters rather than reproductive parameters. This is confirmed in this study, which highlights the great importance of adult survival, as has been described in other studies on marine mammals (Eberhardt 1977, Eberhardt and Siniff 1977, Brault and Caswell 1993, Heppel *et al.* 2000, Gaspar 2003). What is particularly apparent is the importance of changes in adult female survival; approximately between three and ten times more important than changes in age at maturity or fecundity rate. Since this population seemed to be extremely vulnerable to perturbations of this vital parameter, any threat that decreases survivorship of reproductive females is likely to have a serious effect on population growth rates, possibly affecting the ability of the population to recover (Heppel *et al.* 1996, de Krone *et al.* 2000). Therefore, any local conservation strategy should contain specific management actions focused on ways to minimize, anthropogenic pressures and reverse their current impact on the survivorship of adults. In the light of the results from this work, obvious factors to be considered are recreational boating (Chapter 3) and interactions with fisheries (accidental takes). The outcome of the PVA indicates that removals are likely to greatly speed up the extinction process of this local bottlenose dolphin population (Table 6.4 and 6.5), emphasizing the need to mitigate against accidental takes. This finding is a particular cause for concern because of the current observed level of fatal interaction (almost one animal per year between 2000 and 2003, Table 5.4). This mortality seems to be attributable to the illegal practice of using dynamite to fish opportunistically in coastal

zones existing in several areas of the Mediterranean Sea (Commission of the European Communities 2002, Zahari *et al.* 2004) or for forcing pelagic fish upwards during purse-seine operations (Tudela 2004, Mackelworth 2006). The hypothesis is supported by the recent increase in pelagic fish biomass, which is currently considered abundant (Croatian Environmental Agency, http://baza.azo.hr/projekt_more/index.htm, first entered on 18 January 2005) and the consequent strong increase within the study area of pelagic trawling (Stewart 2004).

Given the ongoing debate on the reliability of PVA (e.g. Brook *et al.* 2000, Coulson *et al.* 2001), it seems judicious to highlight that these analyses are not particularly precautionary. In fact, the most “pessimistic” values were not selected as PVA parameters nor was the occurrence of any catastrophic events included in the models. In addition, a number of other important environmental, demographic and genetic processes that can influence the probability of extinction (Keller and Waller 2002) have not been considered here. It is also worth noting that observed rate of decline (0.07, see section 5.3.2) is greater than the deterministic rate of change estimated through PVA (between -0.06 and 0.004; see Table 6.3). In one scenario it is equal to the mean stochastic rate of change estimated through PVA (between -0.07 and 0.002; see Table 6.3). Therefore, the results of these PVAs appear generally more optimistic than the situation recorded between 1995 and 2003.

Small populations, such as the Kvarnerić bottlenose dolphin population, are more likely to become extinct than larger populations, because of their limited capability to cope with stochastic processes (Gilpin and Soulé 1986). The initial size of the population was estimated from 2003 mark-recapture data and appears to be accurate and consistent with the previous three years (Chapter 5). The only information available on age at maturity for the Kvarnerić bottlenose dolphin population is based

on very preliminary work by Pribanic *et al.* (2000) and a relatively small sample size (n=20). Nevertheless the estimated age at physical maturity of 12 years for males and females pooled together is consistent with the values taken from the literature used in the PVAs. The fecundity rate used in this analysis was the mean of all values calculated over the entire study period. This value is optimistic because the mean fecundity rate calculated using only the last three years of the study was 6% lower (Chapter 4). The value of adult female mortality used in the Sex-specific survival case model (SSS) represents an average over a period of nine years. Despite such a cautious attitude, the outcomes from these analyses are rather worrying; therefore they should be taken into serious consideration by National and local relevant authorities.

Extinction risk in these Population Viability Analyses is based on the assumption that, over a given period of time (in this case 60 and 100 years), all demographic parameters and environmental factors will stay the same, unless variability is accounted for (Sanders-Reed *et al.* 1999, Thompson *et al.* 2000). That is, no adjustment has been made for trends in demographic rates or environmental factors over time. This situation is unlikely for a marine mammal living in a highly variable environment, such as the bottlenose dolphin in the Kvarnerić region. Even though PVA accounted for some of this variability, this calculation was based on only nine years of observations and so may not have captured rare, larger scale variation.

Therefore, the shorter-term (60 year) projections are probably more reliable than those over 100 years (Akçakaya 2000b).

The IUCN red-listing process is a useful framework for prioritizing effort and shaping local management schemes for species and populations. Based on the estimated risk of extinction of 35% over the next 60 years (three generations) the Kvarnerić bottlenose dolphin population should be classified as Endangered under Criterion E

(“Quantitative analysis showing the probability of extinction in the wild is at least 20% within five generations, up to a maximum of 100 years”; IUCN 2005). This listing supports that proposed in Chapter 4 (Endangered C2a(i)). Thus, this local population should be listed in one of the “high risk” categories, and urgent conservation action is needed.

In June 2000, the Croatian Parliament ratified many of the international environmental agreements relevant to cetacean protection; particularly the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS), the Convention on the conservation of European wildlife and natural habitats (Bern, 1979), amended in 1996 to cover all Mediterranean Cetacean species; and the Convention on Migratory Species, (Bonn, 1979) (see Chapter 1 for more details). Such a formal step represented the desire to strengthen, at least on paper, the conservation agenda concerning cetacean species. All these political and legal actions will certainly help Croatia in its application for EU status in 2007; however, once it is a Member of the EU, Croatia will be forced to comply with more binding EU Regulations, including the Habitat Directive (Council Directive 92/43 EEC). This will translate into a need to put in place a National Management Scheme to monitor the status of cetacean species (especially and mainly the bottlenose dolphin), in an attempt to mitigate threats. Such an effort will not realistically be possible without the commitment of proper financial resources.

In the next Chapter a detailed conservation plan for this population is proposed, based on the results of this and previous chapters, which contains a specific plan for systematic population monitoring and updating the current PVA.

**CHAPTER 7: GENERAL DISCUSSION: TOWARDS THE
CONSERVATION OF BOTTLENOSE DOLPHIN IN THE NORTH-
EASTERN ADRIATIC SEA**

7.1 SEEKING COMMON CONSERVATION AND MANAGEMENT

OBJECTIVES

Conservation and management objectives must be rooted in existing National and International legislation. Under the new Croatian Law for Nature Protection (Official Gazette No. 162/03, Article 26), all cetacean species are listed as strictly protected. This provision prohibits any action that would disturb or interfere with their natural life cycle and growth, including deliberate capture, holding and killing of animals, disturbance during reproduction and suckling, and trade. Under this protection regime the Croatian Government is expected to promote and support scientific research in the field of nature protection. The Law also prescribes that nature protection requirements need to be issued by the competent government authority (Ministry of Culture) in order to develop natural resource management plans. The National Strategy and Action Plans (NSAPs) for the Conservation of Biological and Landscape Diversity of the Republic of Croatia (Official Gazette No. 81/99 and 128/99) give practical suggestions on conservation and management objectives. The Croatian Law on Environmental Protection (Official Gazette No. 82/94) establishes the goals and basic principles of environmental protection; it also obliges the relevant Authorities to conduct environmental impact assessments, and to finance environmental protection.

By ratifying ACCOBAMS, the Croatian Government has committed itself to meet all conservation objectives of this International Agreement. Particularly, its general conservation objectives including to “take co-ordinated measures to achieve and maintain a favourable conservation status for cetaceans” and to “prohibit and take all necessary measures to eliminate, where this is not already done, any deliberate taking of cetaceans”. Among the non-self-executing obligations arising from ACCOBAMS, which should be regulated through *ad hoc* national regulations and laws, the following seem

to be the most relevant and urgent for the north-eastern Adriatic Sea bottlenose dolphin population:

1. Adoption of measures to minimize adverse effect of fishing activities on the conservation status of cetaceans (Annex 2, par. 1 a) and to prevent fishing gear from being discarded or left adrift at sea (Annex 2, par. 1 b);
2. accomplishment of Environmental Impact Assessments (EIAs) for any new activity that may affect cetaceans as a basis for allowing or prohibiting the continuation or the future development of activities such as fishing, offshore exploration and exploitation, nautical sports, tourism, and cetacean-watching, as well as establishing conditions under which such activities may be conducted (Annex 2, par. 1 c);
3. regulation of the discharge at sea of pollutants believed to have adverse effects on cetaceans, and adopt within the framework of other appropriate legal instruments stricter standards for such pollutants (Annex 2, par. 1 d);
4. establishment and management of specially protected areas for cetaceans as a tool to protect their habitats (Annex 2, par. 3);
5. development of systematic research and monitoring programmes on free-ranging and stranded cetaceans (Annex 2, par. 4).

Concerning item 4 listed above, as mentioned in Chapter 1, the approved “*ACCOBAMS International Implementation Priorities (2002-2006)*” (ACCOBAMS 2002) contemplated the “*development and implementation of pilot conservation and management actions*” (Action 4) in the Kvarnerić (Lošinj-Cres Archipelago) that was identified as one of the most promising areas. To this end, since 2002 a new framework to designate this area as a marine reserve was outlined (*Lošinj Dolphin Reserve*, Mackelworth *et al.* 2002b). In accordance with the new Law for Nature

Protection (Official Gazette No. 162/03, Article 26), it was proposed that the County of Primorsko-Goranska designates the waters East of the Cres-Lošinj archipelago as a ‘*Special Zoological Reserve*’ for the protection of dolphins. Last summer the Ministry of Culture proclaimed this Reserve (see Chapter 1, section 1.2.1). This new status allows for the protection of the area acknowledging the presence of dolphins and other resident, occasional, or rare protected species using this area, including, common and striped dolphins, monk seals, sea turtles, cormorants, etc. Such a protection regime prohibits actions that may cause disruption to those species for which the reserve is designated. The primary objective of this marine reserve was proposed to be the “restoration and maintenance of the population of bottlenose dolphins in the Kvarnerić at a viable level” (Mackelworth *et al.* 2002b). Given the existence of a long-term study (*Adriatic Dolphin Project*) this and other such objectives could be set in a measurable way to monitor progress.

The *Lošinj Dolphin Reserve* is the first dedicated Croatian marine reserve aimed at the protection of cetaceans. This reserve helps fulfil many of the intentions expressed in the National Strategy and Action Plans for the conservation of biodiversity (1999) and, among the other international measures, intentions outlined in the ACCOBAMS and Habitats Directive. In line with this European Directive, this reserve will not only help the maintenance or restoration of favourable conservation status of the Kvarnerić bottlenose dolphin population, but also its habitats (Habitats Directive 92/43/EEC, Article 2.2). The existence of a long-term study based inside the Reserve will ensure the maintenance of a monitoring scheme for the “estimation of size, population trend and protection of dolphins, through the use of a pilot marine park” (Official Gazette No. 81/99). This area is also proposed as part of the Croatian commitment to the *Natura 2000* Network (Habitat Directive 92/43/EEC, Article 3.1), and could be

proposed as a Specially Protected Area of Mediterranean Importance (SPAMI) under the Barcelona Convention.

7.2 OUTLINE OF A NATIONAL AND REGIONAL CONSERVATION

PLAN: OBJECTIVES AND MANAGEMENT ACTIONS

Conservation objectives vary according to the scope of the national or international regulations from which they derive. Such scope has an obvious impact on policies and priorities. For example, according to the Croatian legislation, the bottlenose dolphin as a species, must be protected at national level from direct take, and new protected areas should be established to protect their habitat. Moreover, exhaustive research programmes should be supported by the Government in order to monitor trends in their abundance, taking advantage of studies carried out in protected sites. All activities should, therefore, be directed to conserve this species (population and sub-populations) in Croatian waters. Alternatively, regional or local conservation plans may have only limited geographic scope, and therefore, limited conservation objectives.

Referring back to provisions contained in Croatian legislation and the international agreements ratified by Croatia, some common conservation objectives can be identified. Besides these, additional conservation and management objectives can be inferred from the results of the present work. By merging all these elements it is possible to establish the foundations for the development of a coherent Conservation Plan for the bottlenose dolphin, both at local, regional, and national level (see section 7.2.4 and Table 7.1).

7.2.1 Basic elements of a Kvarnerić bottlenose dolphin Conservation Plan:

Common sense and scientific method

As most principles of decision-making under uncertainty are based on common sense (Ludwig *et al.* 1993), any local management scheme should be adaptive, both in terms of setting priorities (for example, listing and delisting sub-populations), and setting temporal restrictive regulations (for example, on recreational boating or fishing).

Based on the results presented in the previous chapters, a “common sense management framework” should necessarily: a) consider a variety of plausible hypotheses about the status of the Kvarnerić bottlenose dolphins; b) define a set of possible strategies according to those plausible hypotheses; c) prefer management measures that are robust to uncertainties; d) favour actions that are informative, can be monitored and are reversible; e) update assessments and modify policy accordingly (Ludwig *et al.* 1993). Yet, although common sense can be a better compass in a sea of uncertainties than misleading facts, to guarantee fair and correct management when detailing the above listed elements, the scientific method (hypothetico-deductive process) should be applied (Murphy and Noon 1991). For example, data should be collected and analysed accurately, and re-analysed as new tools become available. Each possible management strategy should clarify and quantify aims, setting temporal and spatial scales and operational definitions, to assess its effectiveness. Such rigor is needed for conservation planning in order to achieve credibility and reliability for the proposed measures, both locally and nationally. Ultimately, common sense will guarantee the required flexibility to translate scientific information into conservation policy.

7.2.2 Current Status of the bottlenose dolphin population: potential and identified threats, conservation and research priorities

General results from analyses carried out in this thesis are fully discussed in each Chapter; a brief summary of the main outcomes and their implication for local conservation is given in the following sections.

7.2.2.1. Identification of critical factors affecting the distribution and habitat use

Chapter 3 highlighted a direct negative link between bottlenose dolphin presence and two out of three anthropogenic factors: a) the distance from the three harbours with marine petrol station facilities, that can be considered as a proxy for a diffusive negative effect due to the physical presence of boats; and b) the distance from the main route connecting two of the primary harbours of the archipelago, which corresponds to the presence of fast moving vessels. The latter had a spatially and temporally more localised effect. Both parameters are associated with various types of boat traffic noise, producing mostly low frequency but very high intensity sounds (Rako 2006).

Temporal variation in the impact of these factors was found. In the morning, there was an area with a low probability of encounters for bottlenose dolphins along the main route used by speed boats. However, in the afternoon, when most tourists are anchored in small bays, this displacement did not occur. An overall low use of areas along the coasts of Lošinj and Cres islands was also detected, regardless of the time of day. Seasonal models indicated that effects in summer were similar to those in the morning.

Analysing the data in triennial blocks revealed that the negative relationship between dolphin presence and distance from the main route connecting Lošinj to Rab only became significant during 2001-2003. This may indicate that the current level of boat traffic in some parts of the archipelago exceeds the level that bottlenose dolphins can

tolerate. Moreover, the one-year time lag in the negative correlation between anthropogenic activities and presence of dolphins suggests a longer-term impact, as opposed to the short-term response to the presence of speedboats along the main route between Lošinj and Rab. Even though a lower encounter rate during the summer on the main route connecting Lošinj to Rab could simply reflect an overall lower density, as reflected by the observed decline during the study period (Chapter 5), this explanation is unsatisfactory for two main reasons. First there was a complete absence of encounters along the main route connecting Lošinj to Rab (the “marine highway”) in recent years (2001-2003) (see Fig 3.12); and second, the impact of the observed decline would have been expected to be equally spread over the entire study area.

Bottom depth and trawling areas - two factors that are believed to be directly related to prey distribution - exerted a positive influence on the presence of bottlenose dolphins.

Based on these results, the first steps in a local conservation plan could be to implement the following management and research actions:

1. Definition of seasonal speed regulations for recreational speed boats within the proposed MPA. Fast boats leave less time for the dolphins to take evasive action and also increase the amount of underwater noise (Erbe 2002). Such a regulation could be well defined in time and space, as suggested by the results;
2. Establishment of research for the evaluation of:
 - a. the current status of fish stocks, especially those species for which there is an overlap between bottlenose dolphins and commercial fisheries (for example, hake, anchovies and sardines);

- b. the possible introduction of temporary closed fishing areas, to allow fish reproduction and recruitment;
3. Establishment of a monitoring programme which would allow routine data collection on:
 - a. bottlenose dolphin distribution;
 - b. number of boats registered in the area;
 - c. underwater ambient noise; and
 - d. mechanism of interaction between boats and dolphins.

7.2.2.2 Survival and fecundity rates; temporary and permanent emigration

Chapter 4 provides information about the basic dynamics of the Kvarnerić bottlenose dolphin population. The apparent survival rate for adults was found to be significantly lower than for any other well-studied bottlenose dolphin population (Sanders-Reed *et al.* 1999, Gaspar 2003). The most optimistic explanation is that this reflects a shift in the use of the study area by bottlenose dolphins. The alternative is that mortality rates are high due to environmental and ecological factors (for example, prey abundance and distribution, level of anthropogenic pressure, habitat degradation). The Kvarnerić bottlenose dolphin population did show a high rate of non-random temporary emigration. Differences in type and rates of temporary emigration rates seemed to exist between known females and animals of unknown gender (males and non-reproductive females). The latter seemed to be characterised by a stronger nomadic behaviour in relation to the study area, in contrast to the high fidelity to the study area displayed by reproductive females. Similar fidelity has been observed for other odontocetes, such as the Indo-pacific bottlenose dolphin, Dall's porpoise, harbour

porpoise, killer whale and beluga (O’Corry-Crowe *et al.* 1997, Walton 1997, Escorza-Trevino and Dizon 2000, Möller and Beheregaray 2004).

Two characteristics of the Kvarnerić bottlenose dolphins need to be clarified urgently: 1) its range and discreteness; and 2) the factors that might cause permanent emigration or the depression of demographic parameters.

From a conservation and management point of view, it is vital to confirm or rule out the existence of “discrete population units” and, if they exist, to define the extent of their range. Kvarnerić bottlenose dolphins appear to be quite “resident” (Bearzi *et al.* 1997), but they certainly use a wider area than that covered by this study. There is a strong need to define the area over which they range, in order to determine the most appropriate conservation plan at local, national, and multinational levels. It would be, therefore, valuable to supplement the current voluntary monitoring effort in Kvarnerić by launching photo-identification surveys in adjacent areas. This would allow further investigation of the range of the Kvarnerić local population, and ascertain if it can be considered as an ecologically discrete unit, regardless of the gene flow that seems to exist between the Adriatic and adjacent seas (Natoli *et al.* 2005).

The average monthly capture probability was found to be consistently higher in summer. This was probably due to the better weather conditions and greater research effort. However, the substantial decrease in capture probability registered between May and June during the last biennium suggested that the tolerance of bottlenose dolphins to boaters has been exceeded during this period. A decreasing trend in fecundity rate was also found, together with a high first year mortality for the calves of resident mothers, similar to that observed in other well studied bottlenose dolphins’ population (Wells and Scott 1990, Haase and Schneider 2001, Gaspar 2003). One could speculate that the changes observed in the first five years of this study might

have represented the Kvarnerić bottlenose dolphins' response to some human-induced unbalance in the ecosystem, such as overexploitation of preferred resources (Croatian Environmental Agency, http://baza.azo.hr/projekt_more/index.htm, first entered on 18 January 2005) or increasingly unsuitable physical and acoustic conditions (see Chapter 3). The subsequent decreasing trend of fecundity rate, between 2000 and 2003, might be a consequence of the adjustment of the population to a new, lower environmental carrying capacity (Eberhardt *et al.* 2003).

Some support for this speculation is given by a preliminary comparison of photo-identification data collected near the southern limit of Kornati Island National Park, situated about 100 km south of Kvarnerić. One former-resident reproductive female (id: FED) missing from our dataset since 2001, has been photographed there since 2002 (Impetuoso and Fortuna, *unpublished data*). FED was known in our study area as one of the 11 dolphins most frequently seen feeding behind the bottom trawlers (Prihoda *et al.* 2006). Such speculation is a spur to identify more powerful tools that can help to define the true extent of anthropogenic effects at the population level.

If the shift in the use of the study area is confirmed, new research programmes should focus on understanding the causes. Some hypotheses can be advanced. The only existing information on the status of the fish stocks in the area showed substantial changes in the abundance, size, and assemblage of prey species, highlighting a possible ecosystem changes (for example, the information prepared by the Institute of Oceanography and Fisheries, Croatian Environmental Agency). Preliminary data on the diet of Kvarnerić bottlenose dolphins indicated that in recent years there might have been a change in their diet composition, from demersal to pelagic prey (Stewart 2004). As the bottlenose dolphin is known to be highly adaptable, such a supposed shift seems to be a plausible consequence of the changes in fish assemblage.

An interesting hypothetical link between ongoing changes in the Kvarnerić ecosystem suitability and shift of habitat use by bottlenose dolphins could be the following. In the Kornati National Park, which also experiences a strong seasonal concentration of boats, fishing is forbidden - even though some illegal fishing still occurs - and its waters are known to be very rich. In that region bottlenose dolphins are regularly seen during the summer just outside its borders, probably because of the intensity of boats in the area (Impetuoso *et al.* 2003). One could speculate that such a “no-take zone” could have acted as a reservoir of fish biomass, with surplus fish diffusing out into adjacent waters and attracting dolphins from the Kvarnerić. This hypothesis remains to be tested, and a comparison between these two areas could be revealing.

A change of habitat use could not be confirmed during this work. The Kvarnerić time series of data was not long enough to detect possible returns or “re-colonisation”, and the comparison with photo-identification datasets from other areas within the north and central Adriatic Sea (Gulf of Venice, Slovenian and Istrian waters and Kornati National Park) was only preliminary. However, as time has passed, a more detailed comparative analysis of existing and new data is taking place. These analyses will tackle the question of recolonisation by comparing the present Kvarnerić dataset (1995-2000), with the previous (1990-1994) and, subsequent (2004-2006) ones, and with datasets from other locations within the north and central Adriatic.

7.2.2.3 Trends in abundance

Estimates of abundance presented in Chapter 5 showed that the Kvarnerić population is small and very similar in size to two other European bottlenose dolphin populations: in the Moray Firth, Scotland (129 animals, 95% CI 110-174; Wilson *et al.* 1999), and in the Shannon Estuary, Ireland (113 animals, C.V. 0.14, 95% C.I. 94-161; Ingram 2000). A significant decrease over nine years of about 39% of the initial abundance in

1995 was detected. Based on this decline and the IUCN Red List Criteria, the Kvarnerić population could be listed, at the international level, as Endangered under Criterion C2a(i) (“a population of less than 250 mature individuals, currently declining”; IUCN 2005).

The value of cetaceans in enhancing tourism is well known worldwide, including in Europe and the Mediterranean basin (Hoyt 2001, 2003; Woods-Ballard *et al.* 2003, Parsons *et al.* 2003). Tourism is by far the main source of income for the Kvarnerić region and, although there are no systematic dolphin-watching activities, bottlenose dolphins have been acknowledged as “tourism promoters” and used as an image to advertise this archipelago and Croatia as a whole (Fig. 7.1). Hence, even if this population cannot be considered as an isolated subpopulation, because of some existing degree of genetic exchange with adjacent populations (Natoli *et al.* 2005), a regional listing would have an important meaning for conservation and also from an economic point of view.



Figure 7.1 - Kvarnerić bottlenose dolphins as a tourism image of the island of Lošinj: the award to the Adriatic Dolphin Project by the Tourism Authority of the City of Mali Lošinj acknowledging it as “Tourism Promoter” (left) and one of the panels that welcome tourists at the borders of the Mali Lošinj municipality (right)

According to the power analyses conducted in Chapter 5, the present monitoring regime in the Kvarnerić allows the detection within a short period (3-5 years) of positive or negative rates of change higher than 10% per annum. Given the fact that the population under study is small and showed a strong decline over the past nine years, a continuous and consistent monitoring scheme is highly recommended, to detect any sign of recovery or worsening of the current situation. The current monitoring scheme, which is voluntary and self-funded, seems to be unsatisfactory because too many years of data collection are required to detect important population changes. The extension of the research season to provide more data to increase the precision of the population estimates could almost double the power to detect a trend (Gerrodette 1987). Policy makers should consider this as a matter of urgency, providing financial resources to allow year-round monitoring activities with similar monthly effort to that used in this study.

New analyses of existing mark-recapture data collected in different areas of the Adriatic (e.g. Gulf of Venice, Gulf of Trieste, Istrian coast, Kornati National Park, and Ancona) would allow the total Adriatic population of bottlenose dolphins to be estimated. This could be done by applying, for example, Bayesian multi-site mark-recapture models as was done for data from three locations in Northeast Scotland (Durban *et al.* 2005).

7.2.2.4 Population Viability Analysis

As expected for a K-selected species (Sanders-Reed *et al.* 1999, Heppel *et al.* 2000, Gaspar 2003, Oli and Dobson 2003), population viability analysis (PVA) highlighted the importance of adult survival (Chapter 6). This makes it particularly important that a local conservation strategy should contain specific management actions focused on ways to minimize anthropogenic pressures that impact the survivorship, especially of

adult females. In addition, these analyses made clear how much any additional human-induced mortality would impact Kvarnerić bottlenose dolphin population.

Results of the PVA also highlighted a very high risk (probability = 35%) of local extinction within three generations. Under the IUCN Red List Criteria, these results show that the Kvarnerić bottlenose dolphin population would additionally be listed as Endangered under Criterion E (“*Quantitative analysis showing the probability of extinction in the wild is at least 20% within five generations, up to a maximum of 100 years*”; IUCN 2001).

7.2.2.5 Conclusions based on this study

The scenario depicted does not appear to be favourable for the status of the Kvarnerić bottlenose dolphin population. This local population is relatively small, shows a significant rate of decline, has a low adult survival rate compared to other known populations, has high calf mortality and shows a decreasing trend in fecundity rate. This is exacerbated by the strong seasonal influence of recreational boats which has induced a marked shift in habitat use. All this evidence raises concerns for the population’s conservation status, at least at a local level. In addition to this, results from the PVA clearly identified two major points: 1) any factor affecting adult female mortality has a great impact on population growth and recovery; and 2) the present level of human-induced mortality due to accidental takes and illegal fishing practices (dynamite) is unsustainable. If the present conditions do not change the regional risk of extinction will be soon sufficiently high to list this population as *Critically Endangered* under IUCN criteria (Criterion C1: “*Population size estimated to number fewer than 250 mature individuals and an estimated continuing decline of at least 25% within one generation*”).

Pomerantz *et al.* (1988) developed a classification scheme for the impacts of recreational use on wildlife. Impact categories include: direct mortality, indirect mortality, lowered productivity, reduced habitat use, forcing wildlife into marginal habitat, and disturbance induced stress or aberrant behaviour. In Kvarnerić, the seasonal disturbance caused by recreational boats could have had a negative effect that is synergistic with other factors, helping to fulfill three of Pomerantz's impact categories (lowered productivity, reduced habitat use and forcing wildlife into marginal habitat) in the final years of this study, and indicating that mitigation measures should be considered as a matter of urgency.

There is circumstantial evidence to suggest that bottlenose dolphins may have been expending more energy avoiding boats in this area between 2001 and 2003 than in earlier years, and that in the same period some animals may be staying away from their preferred habitat. In the longer term, this might result in dolphins, which have a high tourist value in the area, moving elsewhere. Animals that remain might have reduced survival rates. In view of this, serious concerns arise from the recent proposed plan for the construction of a new Marina in Nerezine within the Zoological Reserve (Fig. 7.2). The construction plan was preliminarily accepted after an EIA, which disregarded the existence of the resident population of bottlenose dolphins in the area. A new EIA should be carried out on the impact that the construction and existence of a new Marina would have on resident populations of protected species before any building permit is released.

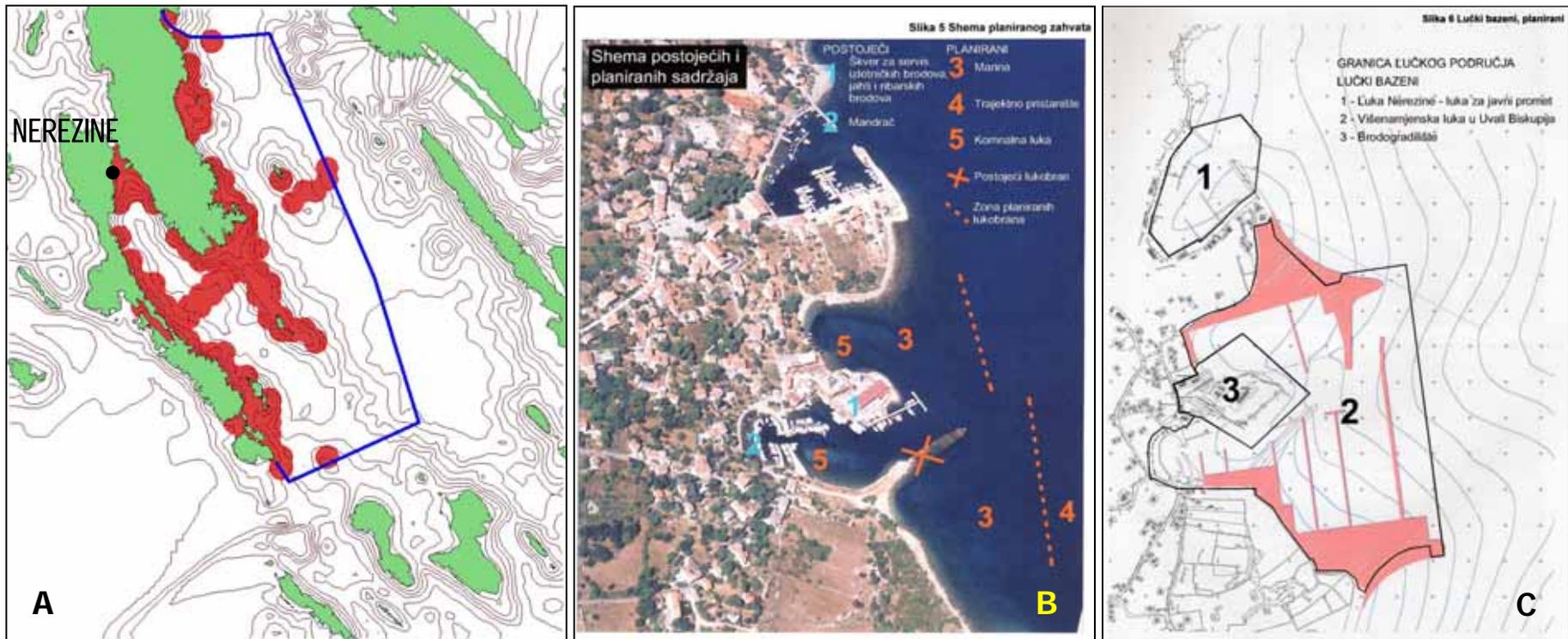


Figure 7.2 - Map of the Special Zoological Reserve (blue boundaries), with the red buffers of the summer exclusion zones (A); aerial view of Nerezine (B) and plan for the construction of the new Marina (C)

7.2.3 Conservation objectives for the Kvarnerić bottlenose dolphins

When defining a framework for the Kvarnerić bottlenose dolphin population Conservation Plan, the existence of a considerable amount of information allows us to take into account the status of the animals, and some of the known and potential threats. This will allow the proposal of mitigation measures to reduce or eliminate those threats and a monitoring programme. This Conservation Plan will ultimately provide a draft framework on which to build a local or national Management Scheme. From a local perspective, now that the Special Zoological Reserve has been declared, the conservation objectives need to be shaped by the geographic context, and the local socio-economy. For example, as bottlenose dolphins have proved to be a powerful engine for the promotion of local and regional tourism (Mackelworth 2006), local authorities will need to ensure that conditions are suitable for them to remain within the boundaries of the Reserve. This would then be one of the the main conservation objectives, regardless of whether these dolphins are a population, a sub-population or just a group inhabiting these waters. For the same socio-economic reason, this objective could be extended to a hypothetical Conservation Plan for the County Primorsko-Goranska (Kvarner and Kvarnerić areas) and even for Croatia.

Other conservation objectives should be: i) the prevention of spatial and genetic fragmentation caused by human-induced exclusion areas, ii) the mitigation of identified threats (for example, unregulated recreational boating and lethal interactions with fisheries), iii) the maintenance/recovery of food resources in the area and iv) identification of all other possible threats.

Based on these objectives, any Management Plan for the Zoological Reserve will have to assess and address any activities that could have adverse effects on the population. The Management Plan will have to specify how these activities may be regulated by

relevant authorities. Such control and regulatory mechanisms should be accommodated in ways that are acceptable to both the local community and the conservation objectives. An effective Management Plan should not set out to be static, but to be an ongoing process that aids decision making, continually evolving to take account of changing issues and new legal obligations. Scientists, for example, should not be afraid of giving positive news that can lead to delisting or down-listing threats or endangered species, or to changes in restrictive regulations that are no longer required. Such a mechanism could help to build trust in local communities, which would then be more inclined to accept new restrictions, proposed by managers and supported by scientists, when really needed. Effective governance is easier to achieve when processes are transparent and communities maintain face-to-face communication that increase the potential for trust (Dietz *et al.* 2003). The Management Plan should be developed and implemented by a Management Group composed of the Relevant National and Local Authorities involved in the site, representatives of civil society, and relevant specialists in the fields of conservation biology, socio-economics, etc.

7.2.4 Draft Conservation Plan: a National perspective

Although the data presented here do not depict an optimistic scenario for the future, it is clear that they do establish a scientific foundation on which a good management framework can be built. The existing Adriatic Dolphin Project (ADP) dataset (1987-present), the experience gained in conducting research on cetaceans, and the results presented in this thesis allow research and conservation priorities to be highlighted in detail, not only at the local level.

The objective of this work was not to produce a complete Conservation Plan for the bottlenose dolphin in the north-eastern Adriatic Sea, but to provide science-based indications of which factors may be affecting the Kvarnerić bottlenose dolphin

population. However, this study has also made it possible to draft some of the needed elements for a National Conservation Plan.

All the new information presented in this work is of fundamental importance because it has the potential to facilitate the work of relevant National Authorities toward the implementation of international and national protection laws for bottlenose dolphins. For example, based on the above observations, four management actions seem particularly urgent, the first two also having a National scope. These are: 1) to protect mature individuals (particularly females), 2) to prevent any incidental take (by-catch and any other fishery-related death), 3) to regulate locally the recreational boating, at least in the observed exclusion area (the Mali Lošinj-Rab marine highway), and 4) to re-assess the impact of the proposed new Marina on all protected species using the Nerezine channel.

Besides these urgent management actions that can be implemented relatively quickly because they only require a strong enforcement of existing national laws and regulations, a serious effort must be made by the National Authorities to establish a routine monitoring scheme.

Information on trends in abundance and absolute abundance estimates, together with data on population structure, mortality and reproductive rates, is needed to identify populations for which management actions are required (Thompson *et al.* 1998, Beissinger and McCullough 2002, Morris and Doak 2002, White *et al.* 2002, Evans and Hammond 2004, IUCN 2005). Management schemes should be designed to estimate such baseline data for all populations and strictly monitor the effectiveness of management schemes when they are in place (Taylor and Gerrodette 1993; Thompson *et al.* 1998, Wilson *et al.* 1999b; Evans and Hammond 2004, Williams *et al.* 2001). This becomes particularly necessary when Governments have made commitments to

international agreements on conservation of species and habitats, especially when such regulations are binding for Parties (e.g. the EU Habitats Directive).

Targeted studies should explore the use of new analytical methods for analysing mark-recapture data from multi-sites (Durban *et al.* 2005), and on extinction risk modelling (Goodman 2002, Wade 2002, Maunder 2004). Current PVAs will need to be recursively recalibrated to allow listing, delisting or down-listing of the bottlenose dolphins and to refine estimates of relative extinction risk. Retrospective analysis carried out on the whole ADP dataset (1987-present) should be used to identify patterns of variation and assess the reliability of the trends detected in this study. Research should be designed to study the processes affecting variation in survival and abundance, particularly with regard to questions about the effectiveness of management actions.

Dedicated photo-identification surveys, which allow precise estimates of demographic parameters, should be conducted systematically in at least four other locations besides Lošinj. These could be two locations relatively close to the study area and another one more distant (Kornati archipelago, Rijeka bay, north-eastern Istrian coast and the archipelago off Split). Data from these sites would help clarify the structure and ranging patterns of the Kvarnerić population (or Kvarnerić sub-population), and the possible existence of other sub-populations. International partnerships on such surveys, particularly with Slovenia and Italy, could help to further the understanding of the structure and dynamics of the bottlenose dolphins in the Adriatic. This is fundamental information required to develop a meaningful conservation plan for the entire Adriatic Sea (a semi-enclosed sea).

Photo-identification data could be supplemented through genetic sampling of free-ranging animals, not only stranded animals because sea currents and strong winds could easily mix dead floating individuals from different areas. Thus samples could be

collected from stranded specimens from all Croatian coasts, enlightening the possible meta-population structure, and locally to evaluate if inbreeding could be a factor in increasing the extinction risk for the Kvarnerić population.

This type of monitoring activity should be made in conjunction with a systematic plan for aerial surveys over the entire Croatian waters. Such a monitoring plan, for example made of triennial or quinquennial surveys, carried out in each season, would give a total abundance estimate to compare with local photo-identification based mark-recapture estimates and a measure of potential “migratory patterns”.

A specific monitoring programme should be launched to examine direct and indirect interactions with fisheries. In particular, independent observers should be used to estimate the by-catch rate in different fishing gears. In addition, a specific project on depredation should be carried out in those areas where such interactions are known to take place (for example, the Brijuni islands). Finally, all existing data on the status of fish resources in Croatia should be integrated and gaps filled with new research programmes, particularly on bottlenose dolphin prey that are of commercial interest.

Based on experimental findings gathered on the north-eastern Adriatic bottlenose dolphins, some obvious evaluations on pollution, and the Croatian legislative background relevant to this species (see sections 1.2. and 7.1) a concise summary of the fundamental elements defining conservation and management objectives, their legislative justifications and some of the ensuing management actions, is presented in Table 7.1. A complete National Conservation Plan should contain also Capacity Building and Public Awareness activities, and evaluate all socio-economic aspects; however, given the nature of this work, those aspects were not examined here.

Table 7.1 – Fundamental elements for a National Conservation Plan

Long-term conservation objectives	Management objectives	Legislative justification	Actions to be taken (Prioritised: High, Medium)
<ul style="list-style-type: none"> Maintenance of the species in the region (distribution, abundance and genetic fragmentation) 	<ul style="list-style-type: none"> To prohibit and take all necessary measures to eliminate any deliberate taking of cetaceans 	Official Gazette No. 162/03 and ACCOBAMS ratification	H: Control of the compliance with the existing laws
	<ul style="list-style-type: none"> Estimation of the size, population trend, through Use of a pilot marine park for monitoring programmes 	Official Gazette No. 81/99 and ACCOBAMS ratification	H: Creation of a national stranding network and tissue bank H: Development of systematic research and monitoring programmes M: Implementation of a periodical national snapshots on abundance (triennial national surveys) M: Networking of existing projects
<ul style="list-style-type: none"> Maintenance or restore of habitat quality (food resources availability and pollution) 	<ul style="list-style-type: none"> To minimize adverse effect of fishing activities on the conservation status of cetaceans 	ACCOBAMS ratification	H: Launch of new monitoring programmes on by-catch and depredation H: Systematic analysis of stomach contents H: Overview on existing data on fish abundance M: Identification of case studies for modelling competition for resources
	<ul style="list-style-type: none"> To establish an Environmental Impact Assessments (EIA) framework for any new activity that may affect cetaceans, establishing conditions under which such activities may be conducted 	Official Gazette No. 82/94, 81/99, 128/99 and ACCOBAMS ratification	H: Creation of a framework for a cetacean risk assessment module to be included in the standard EIA procedure

Table 7.1 (continued) – Fundamental elements for a National and regional Conservation Plan

Long-term conservation objectives	Management objectives	Legislative justification	Actions to be taken (Prioritised: High, Medium)
<ul style="list-style-type: none"> Maintenance of the species in the region (distribution, abundance and genetic fragmentation) 	<ul style="list-style-type: none"> Establishment and management of protected areas for protected species Restoration and/or maintenance of the population of Kvarnerić bottlenose dolphins in the MPA at a viable level Network of marine protected areas 	Official Gazette No. 81/99 and ACCOBAMS ratification	H: Implementation of the designed Lošinj Special Zoological Reserve M: Creation of a network of national protected areas used by cetaceans (for example, Brijuni and Kornati Marine National Parks) and planning of coordinated research activities on sensitive topics (for example, depredation or unsustainable nautical traffic) M: Definition, implementation or update of Management Schemes including cetacean issues
	<ul style="list-style-type: none"> Regulation of the discharge at sea of pollutants 		Official Gazette No. 17/94, 74/94, 108/95, 27/96, 43/96 and ACCOBAMS ratification
<ul style="list-style-type: none"> Maintenance or restore of habitat quality (food resources availability and pollution) 	<ul style="list-style-type: none"> International co-ordinated measures to achieve and maintain a favourable conservation status for cetaceans in the Adriatic sea 	ACCOBAMS ratification	H: Multilateral agreement for research on cetaceans in the Adriatic sea H: Definition of an Adriatic Conservation Plan for the bottlenose dolphin H: Development of synergistic activities between national and international research programmes relevant for the conservation and ecology of bottlenose dolphins

7.4 THE CURRENT IMPASSE OVER THE ZOOLOGICAL RESERVE

During the ACCOBAMS First Meeting of the Parties, held in Monaco in 2002, ACCOBAMS International Implementation Priorities for 2002-2006 were approved, including the *“Development and implementation of pilot conservation and management actions in well-defined key areas containing critical habitat for populations belonging to priority species”* (Action 4) (ACCOBAMS 2002). Under this Action four areas were identified as promising candidates, one of which was the Kvarnerić area (Lošinj-Cres Archipelago). At the Sixth meeting of National Focal Points for Special Protected Areas (UNEP RAC/SPA), held in Marseilles in 2003, Croatia reported among the *“Collaborative activities undertaken within the framework of the implementation of the Protocol and/or the Action Plans, especially at bilateral or sub-regional levels”* the fruitful co-operation with the Principality of Monaco on several nature protection projects. In particular, a project for the evaluation of the area around Cutin islands, included in the Cres-Lošinj archipelago, as a potential marine reserve important for dolphins and sea turtles was brought to the attention of the meeting. This cooperation included the research project on *“The identification of critical habitats and the analysis of management procedures for the future Lošinj-Cres marine protected area”*.

However, after the designation of the Zoological Reserve that previously was very well supported by the former local and National authorities, its implementation came to an abrupt halt after strong pressure from the investors in the new Marina planned in Nerezine. This situation has worsened due to the fact that the EIA made for its construction disregarded the existence of dolphins in the area. However, it did consider the issue of the impact on the, at that time, proposed Reserve, stating that the *“new Marina will comply with the regulation of the new MPA once designated”*. The work presented in this thesis has demonstrated the urgency of the implementation of a

Management Plan and Body in order to address all concerns on the Kvarnerić bottlenose dolphin population and of local stakeholders.

7.5 FINAL REMARKS

The Kvarnerić bottlenose dolphin is the subject of one of the longest ongoing projects in the Mediterranean on this species (*Adriatic Dolphin Project 1987-present*, ADP). The population is showing clear signs of distress and requires immediate management action. In 2005 Croatia entered the circle of Candidate Associated Countries to the European Union and is now required to take steps towards European standards, including in the area of nature conservation. The results of the work done by the ADP, a small NGO, especially during the last quinquennium, could represent a good foundation on which to build a National and local conservation and management strategy for bottlenose dolphins. However, National conservation policy should not rely only on the goodwill of an NGO; conservation efforts should be well planned and coordinated by the relevant Authorities. Acceptance of current knowledge, the use of the existing expertise and the implementation of the proposed strategy could potentially lead to the same outcome as David *vs.* Goliath, with Croatia becoming an example of good practice for cetacean conservation. All action proposed here is needed from both the perspective of bottlenose dolphin conservation and the Croatian nation.

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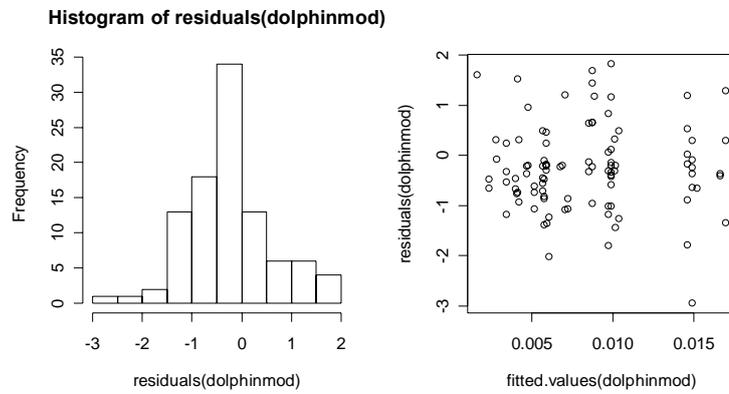
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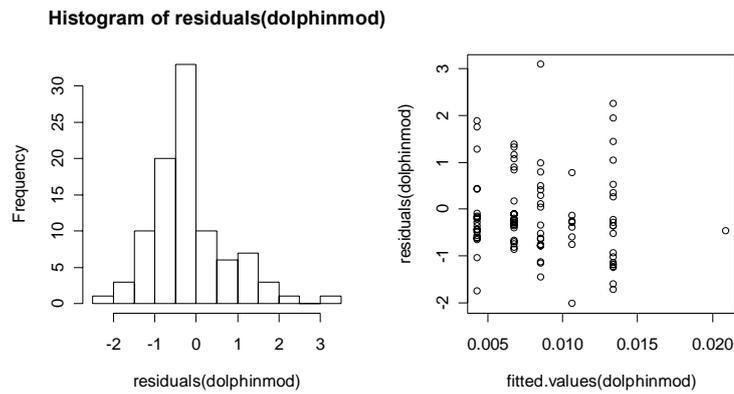
**ANNEX 1: RESULTS OF GLM ANALYSES AND GRAPHS OF
RESIDUALS NOT PRESENTED IN CHAPTER 3**

2. GRAPHS OF RESIDUALS OF GRID1000 GLMs NOT PRESENTED IN CHAPTER 3

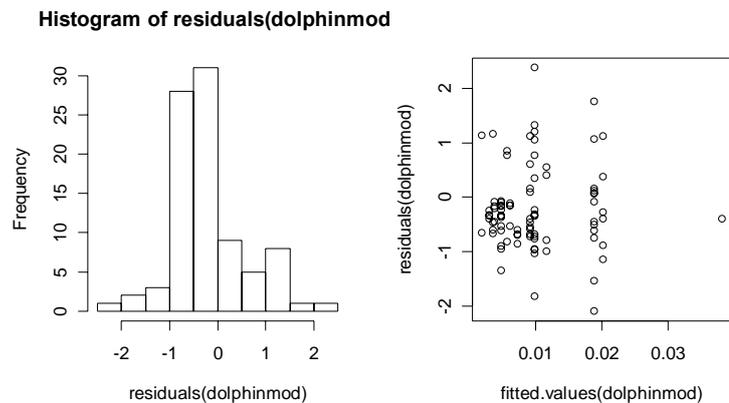
SUMMER MODEL:



ALL OTHER SEASONS MODEL:

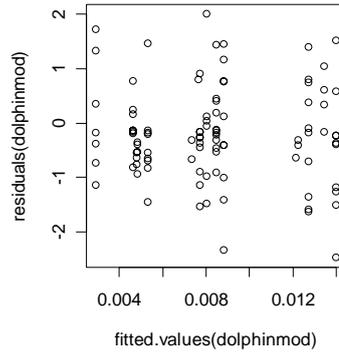
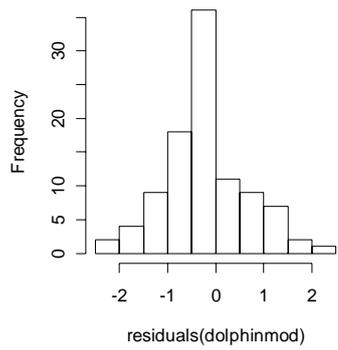


MORNING MODEL:



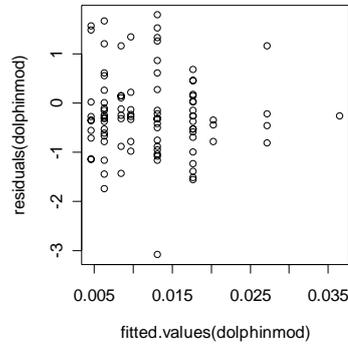
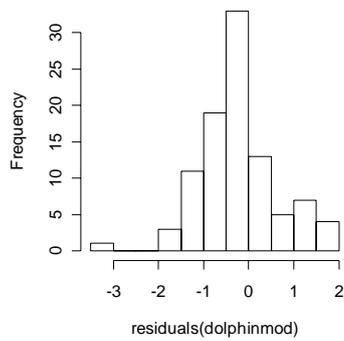
AFTERNOON MODEL:

Histogram of residuals(dolphinmod)



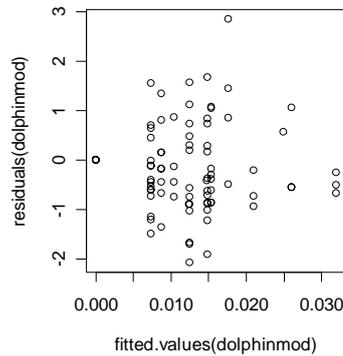
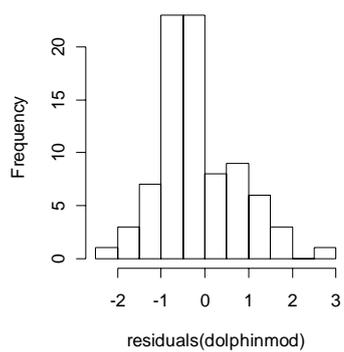
“1995-1997” MODEL:

Histogram of residuals(dolphinmod)



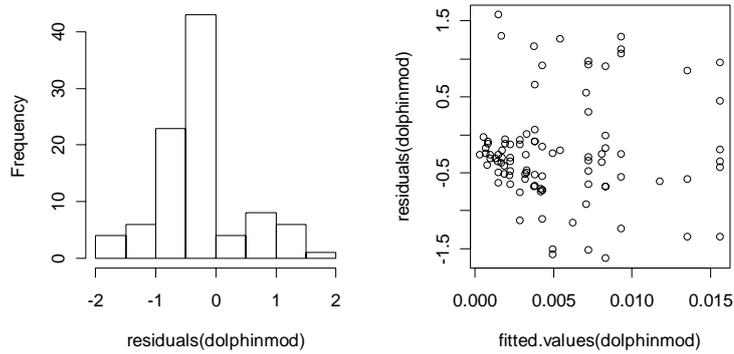
“1998-2000” MODEL:

Histogram of residuals(dolphinmod)



“2001-2003” MODEL:

Histogram of residuals(dolphinmod)

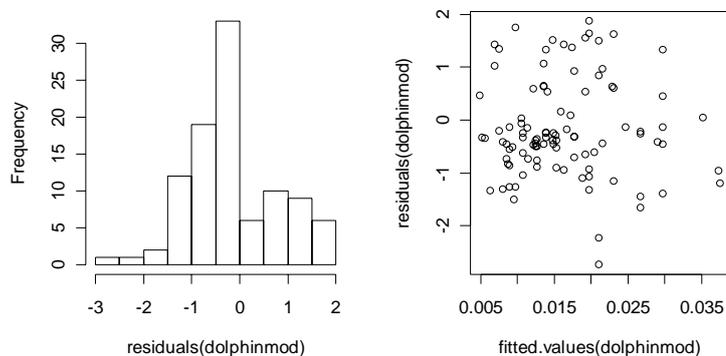


2. RESULTS AND GRAPHS OF RESIDUALS OF GRID2000 GLMs NOT PRESENTED IN CHAPTER 3

“ALL DATA” MODEL:

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-6.117e+00	2.602e-01	-23.508	< 2e-16	***
Depth	1.917e-02	8.024e-03	2.389	0.0169	*
I(Depth^3)	-2.396e-06	9.968e-07	-2.404	0.0162	*
MAN.FIX	5.048e-05	9.979e-06	5.058	4.23e-07	***
Trawling	3.149e-01	1.388e-01	2.269	0.0233	*

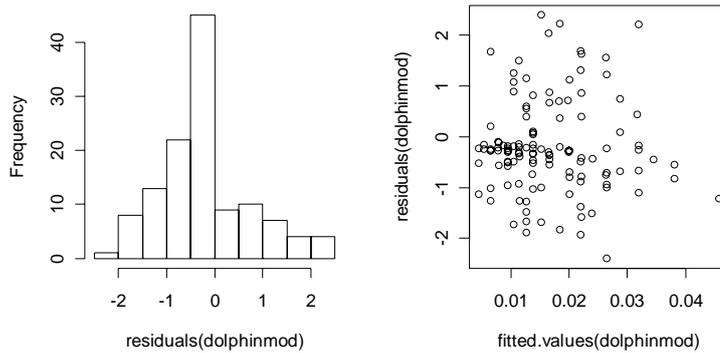
Histogram of residuals(dolphinmod)



SUMMER MODEL:

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-5.676e+00	2.678e-01	-21.199	< 2e-16	***
Depth	1.056e-02	3.870e-03	2.728	0.00637	**
MAN.FIX	6.229e-05	1.256e-05	4.959	7.1e-07	***
Trawl	4.755e-01	2.052e-01	2.318	0.02046	*

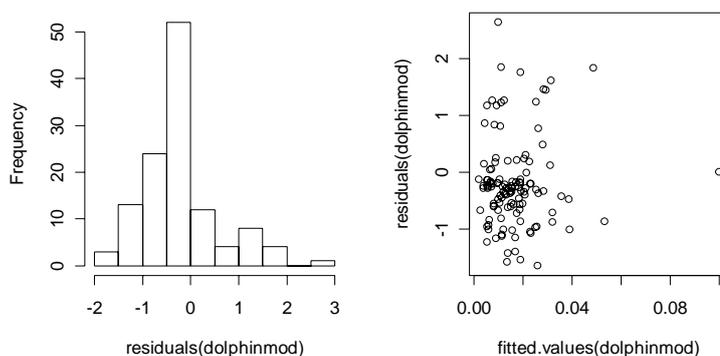
Histogram of residuals(dolphinmod)



ALL OTHER SEASONS MODEL:

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-4.092e+00	7.991e-01	-5.121	3.04e-07	***
Depth	1.124e-02	6.970e-03	1.613	0.10674	
Slope	-3.248e-02	2.446e-02	-1.328	0.18421	
Distance	-5.590e-04	2.752e-04	-2.032	0.04220	*
MAN.FIX	5.446e-05	1.928e-05	2.825	0.00473	**
LnMAN.MOV	-6.130e-01	2.975e-01	-2.061	0.03935	*
I(LnMAN.MOV^2)	5.835e-02	2.914e-02	2.003	0.04522	*
Trawl	6.602e-01	2.993e-01	2.206	0.02739	*
Slope:Distance	2.138e-05	1.065e-05	2.007	0.04473	*

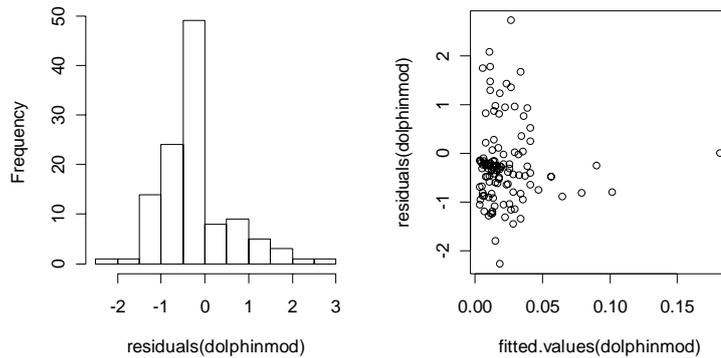
Histogram of residuals(dolphinmod)



MORNING MODEL:

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-6.026e+00	5.472e-01	-11.014	< 2e-16	***
Depth	1.078e-02	6.694e-03	1.611	0.10721	
Slope	2.266e-03	1.465e-02	0.155	0.87708	
Distance	-3.845e-04	1.996e-04	-1.927	0.05402	.
MAN.FIX	8.064e-05	1.912e-05	4.218	2.46e-05	***
Trawl	8.125e-01	3.048e-01	2.666	0.00769	**
Slope:Distance	1.510e-05	7.429e-06	2.033	0.04210	*

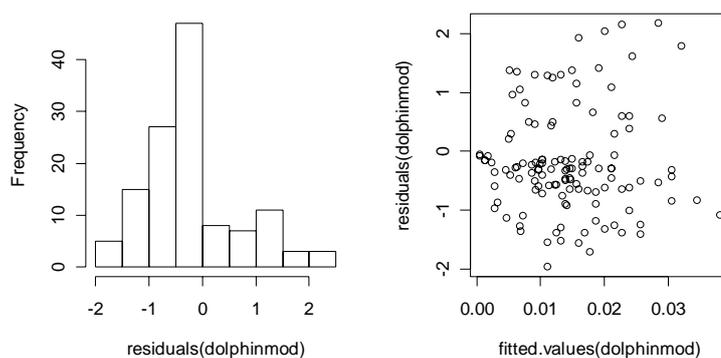
Histogram of residuals(dolphinmod)



AFTERNOON MODEL:

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-4.425e+00	6.673e-01	-6.630	3.36e-11	***
Depth	9.839e-03	4.301e-03	2.288	0.022166	*
Slope	-3.204e-02	2.074e-02	-1.544	0.122474	
MAN.FIX	5.058e-05	1.390e-05	3.638	0.000274	***
LnMAN.MOV	-4.356e-01	2.281e-01	-1.910	0.056138	.
I(LnMAN.MOV^2)	4.448e-02	2.205e-02	2.017	0.043672	*
Trawl	5.024e-01	2.228e-01	2.255	0.024160	*

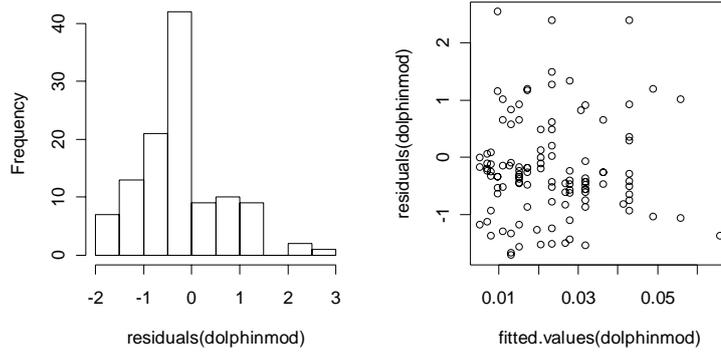
Histogram of residuals(dolphinmod)



“1995-1997” MODEL:

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-5.627e+00	2.835e-01	-19.847	< 2e-16	***
Depth	1.732e-02	4.839e-03	3.580	0.000343	***
MAN.FIX	7.473e-05	1.569e-05	4.764	1.90e-06	***

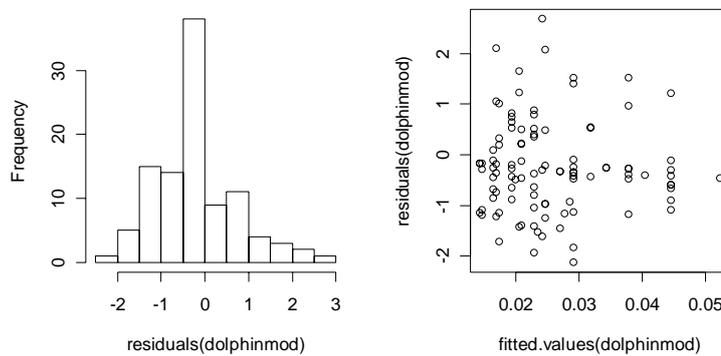
Histogram of residuals(dolphinmod)



“1998-2000” MODEL:

	Estimate	Std. Error	z value	Pr(> z)	
(Intercept)	-4.314e+00	2.178e-01	-19.804	<2e-16	***
I(Depth^3)	1.556e-06	6.752e-07	2.304	0.0212	*
MAN.FIX	2.812e-05	1.720e-05	1.635	0.1020	

Histogram of residuals(dolphinmod)



“2001-2003” MODEL:

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	16.50903	2144.08621	0.008	0.994
Depth	-0.46420	47.64636	-0.010	0.992
Slope	-0.86346	88.72080	-0.010	0.992
LogMAN.MOV	-0.47832	0.33654	-1.421	0.155
I(LogMAN.MOV^2)	0.04574	0.03282	1.394	0.163
Depth:Slope	0.01982	1.97157	0.010	0.992

Histogram of residuals(dolphinmod)

