Living Resources Committee

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REPORT OF THE

STUDY GROUP ON THE BIOLOGY AND LIFE HISTORY OF CRABS

Brest, France
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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1 INTRODUCTION

1.1 Participants

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1.2 Terms of Reference

The Study Group (SGCRAB) (Chairman, R Dufour, Canada) met at Ifremer, Brest, France from 4–7 May, 1998 with the following terms of reference (C Res.1998/ 2:48):

a) review the commercially important crab species under ICES mandate;

b) review the present knowledge on the biology, life history, and fisheries of these species;

c) review the assessment methods (direct and indirect) in use for crabs;

d) elaborate and update biological reference points on crab harvesting strategies and protection of the stock reproductive potential under the present exploitation regimes specific to each species;

e) assess the potential no harvest marine protected areas might have both in conserving crab population reproductive potential and in protecting important habitat used by crabs in their life cycles;

f) assess the future production potential of crabs in Europe taking into account the factors affecting quality;

g) assess the impacts crabs, particularly introduced crab species, have on nearshore community and bivalve mariculture

1.3 Background of the Study Group

The first meeting of the Study Group on crab met in Jersey, UK, in 1993 to review progress on the research and fishery management of two commercially important Majidae species, the spider crab (*Maja squinado*) and the snow crab (*Chionoecetes opilio*), fished on the two sides of the Atlantic and in the Pacific, as reported in CM 1993/K:3. The Study Group recognized the need for more intensive coverage of the life history particularities of the two species, and a better geographical representation of crab experts, leading to a second meeting at La Coruna, Spain, which reviewed new information available on the life history and fishery management of the Spider crab and *Chionoecetes* species (*opilio, bairdii, tanneri*), as reported in CM 1996/K:1. It was recommended that the SGCRAB should meet on a 3 years basis and that the remit be enlarged to include other commercially important crab families, notably portunid and cancrid crabs which are not covered by ICES assessment working groups or study groups. This third meeting of the SGCRAB group was convened on the basis of Council Resolution 1998/2:48.

2 PRESENT KNOWLEDGE ON THE BIOLOGY, LIFE HISTORY AND FISHERIES OF COMMERCIALLY IMPORTANT CRAB SPECIES IN EUROPE AND CANADA

2.1 Crab fisheries in Europe

2.1.1 Crab fisheries in France

Edible crab (*Cancer pagurus*), spider crab (*Maja squinado*), velvet crab (*Necora puber*) and shore green crabs (*Carcinus maenas* and *C. aestuarii*) are commercially harvested along the French Atlantic coast and the English Channel. Landings of these species totalled 11 000 to 12 000 t (estimation for 1997). Along the French Mediterranean coast, abundance of commercially harvested crabs is low and landings do not exceed 100 t (mainly *C. estuarii).*

Fishing gears are mainly pots and traps for all crab species but locally tangle nets are also used for spider crabs. Occasionally, trawlers land small catches of spider crab and velvet crab. Potting takes place in depths from 0 to 200 meters but most of the catches are from the range 10 to 100 meters.

The fishery comprises a thousand boats, full time or more frequently on a seasonal basis. About 20 of these are "large potters", 17 to 25 meters long, fishing for crab all year round during neap tides on various grounds often at 10 hours or more from their harbor. Trips last 7 to 10 days at sea followed by 4 to 7 days in the harbor. The other boats are 5 to 16 meters long, going at sea daily during the season and exploiting grounds within 30 nautical miles from the coast.

On most fishing grounds, boats can catch lobster (*Homarus gammarus*) as well as crabs, and each day boats will possibly set some strings targeted mainly on crabs and others mainly targeted on lobsters in proportion to the commercial ratio the fisherman wishes to land. From an administrative point of view, crabs and lobster potting are currently the same "métier" and it is generally difficult to establish for scientific purposes what proportion of the of fishing effort is dedicated to each species. In addition landing figures for small boats, which represent the greatest part of the fleet, used to be poor, although an improvement in the quality of the figures is on the way.

Until 1997, access to the crab and lobster fishery was unrestricterd, and the fishery was only regulated by a minimum landing size except locally for a short closed season for spider crab. Principal regulations are:

- Minimum landing sizes (MLS):

  Cancer pagurus: 14 cm carapace width (CW) north of 48°, 13 cm width south of 48°.
  Maja squinado: 12 cm carapace length (CL).
  Necora puber: no MLS (5 cm CW was implemented by Industry previously, but currently has no legal support).
  Carcinus maenas: no MLS

- The landing of recently molted crab is prohibited for all species but not totally enforced.

- In 1993 the Comité National des Pêches Maritimes et des Elevages Marins (Industry at the national level) proposed that a fishing licence be compulsory for large crustacean (crab and lobster) fishing, but implementation was beyond responsibility of the Provinces. After some years required to obtain agreement from all the Provinces, restricted access was implemented. In 1998 a debate commenced on how to limit (decrease) the number of boats with a licence.

- Parlor pots are forbidden in all areas except Basse Normandie and a restricted part of north Brittany, where potters work on the same stock and grounds as boats from Jersey which use parlor pots.

2.1.2 Edible crab in France

Growth has been studied in the Western Channel and the Bay of Biscay by tagging (1981 to 1984) and recapture experiments. Von Bertalanffy growth curves were as follows (Latrouite et Morizur, 1988a), in which L refers to carapace length:

$$\text{Male } L_t = 140\,[1 - e^{-0.39(t-0.83)}]$$
$$\text{Female } L_t = 130\,[1 - e^{-0.25(t+0.82)}]$$

Studies on reproductive cycle and size at maturity of female edible crabs from Western Channel indicate that spawning occurs mid November to beginning of January (Latrouite and Noël, 1993). The mean size at first spawning is between 85 and 90 mm carapace length. In most cases molting and spawning occur in the same year, sometimes separated by no more than three months.

Migration in the Western Channel and Bay of Biscay has been studied by tagging (1981 to 1984) and recapture experiments (Latrouite et Le Foll, 1989). Males show only short distance displacement, with no preferential orientation. Females show long distance (often more than fifty nautical miles) and oriented displacement in the direction opposite to the residual currents, which presumably compensates for the drift of larvae.

Unusual winter mortalities observed in the 1980's led to the identification of a Hematodinium-like parasitic dinoflagellate in the blood of *Cancer pagurus* (Latrouite *et al.*., 1988). The parasite was found on crabs from all fishing areas where samples had been taken (English Channel, Irish Sea, Biscay Bay, off Scotland). Prevalence was found to be independent of the intermolt stage, sex and size of crabs but was higher onshore than offshore. The pathogenicity was assumed to differ according to the season.

A sampling program has been conducted from 1981 to 1987 on catches from inshore and offshore French potters fishing in the English Channel, Irish Sea and on the shelf (Latrouite et Morizur, 1988 b). Principal component analysis of the data showed seasonal changes in sex ratio (more male from December to April than from May to November) and that spatial heterogeneity was more important than temporal heterogeneity. No significant changes in catch composition have been detected during the period 1981 to 1987.

The fishery expanded at the beginning of the 1970's and landings reached a maximum in 1977 (officially 11 000 t, possibly around 15 000 t). Then catches decreased until 1991, probably after the greatest part of accumulated biomass had been fished. Since then landings have stabilised around 6 000 to 7 000 tons.

Catch and effort of a fleet of offshore potters from Morlaix district specializing on edible crab have been studied over the period 1985 to 1996 (Latrouite and Noël, IFREMER laboratory report) and catch per unit effort was derived from their logbooks. This fleet, operating on various grounds in the Western Channel, the Bay of Biscay and in southeast Ireland (ICES division 7E, 7F1, 7G2, 7H2, 8A), is responsible for more than one third of the national landings of edible crabs. The total number of pots hauled by the fleet increased from 1986 to 1990, then remained more or less constant. The corresponding CPUE, all areas combined, decreased from 1985 to 1989 and increased regularly from 1991 to 1996.

No good data on catch per unit effort are available at the moment for inshore fleets but the general feeling is that recruitment to the fishery was rather good during recent years (although this does not mean that edible crab potters are prosperous, because of the constantly low market prices). An increase of abundance of edible crab is even reported by fishermen in such areas as the southeastern part of the Western Channel, where edible crabs used to be rather scarce.

2.1.3 Edible crab studies in Ireland

A database on fishery performance, size structure of the catch, and tagging data for the largest *Cancer pagurus* fishery in Ireland (off the north east coast) was presented at the meeting. Data on landings, effort and catch rates for the inshore and offshore components of the fleet were compiled for the period 1991 – 1997. This two year project was funded by the Marine Institute, Dublin and the Irish Sea Fisheries Board (BIM).

The fishery for *Cancer pagurus* off the north west coast of Ireland represents approximately 75 % of the national catch, landing over 3500 t per annum. The catch is taken by a fleet of vivier boats operating offshore, fishing at depths of up to 200 m and landing their catch typically once per week, and partly by a larger fleet of smaller vessels operating up to 20 miles offshore and landing on a daily basis. The offshore fishery began in 1992 whereas the inshore fishery is of longer standing. Effort in both fleets has been increasing and there is concern over falling catch rates.

The database comprises:*Variables relating to fishery performance*: Date, Port, vessel name, owner, vessel size, latitude and longitude or sea area fished, number of pots fished, catch; *Variables relating to standardizing catch rate data*: soak time, wind direction, wind strength, atmospheric pressure, temperature; *Biological information on the catch and the population:* Size structure of the catch, landings and discards, sex, proportion soft shelled, proportion with sperm plugs. Size at maturity (morphometric and physiological maturity), fecundity at size data. *Movement and growth:* Data is held on over 4000 crabs tagged and released in the fished area during 1996 and 1997. These crabs are re-released on capture giving the possibility of multiple recaptures of the same individual. Latitude and longitude and carapace width of all releases and recaptures are recorded for each individual crab.

Fishing location data for the offshore fleet are collected on a very fine spatial resolution. Latitude and longitude is collected for the beginning and end of each string of approximately 100 pots. Data on size structure of the catch can be associated with a particular string of pots. This resolution makes it possible to analyze data at different spatial scales and to look at micro-scale differences in catch rates and size structures. As the precise location and behavior of the fleet is known and fishing tends to be aggregated in different locations depending on the time of year the data can be treated as a spatial and temporal series of depletion experiments that can be analyzed by the Leslie and DeLury methods. Size structure of the catch can be raised in a particular sequence from string up to fleet for a particular fishing day. Data can be used in length cohort and yield per recruit analysis.

The database interfaces with a data entry and visualization facility written in Visual Basic. This interface allows fisheries co-operatives, crab processing plants or individual vessels to view a historic series of data for a given location and to continually update the information submitted by the vessel owners. The database will be updated centrally to build on the data series and facilitate more robust and diverse analyses.

A paper on the early benthic phase of Cancer pagurus (Robinson and Tully, 1998) was presented, as summarised below:

Cohort strength in decapod crustaceans may be determined early in the life history and particularly at settlement if megalopae settle into habitat where competition for resources is high. Density dependent mortality may operate at this stage either through intra or interspecific competition. If settlement and recruitment into the benthic habitat are under density dependent constraint and the area of habitat is limited then these life history processes could control the stock recruitment relationship and the carrying capacity and production of the population. However, very little is known about settlement or the processes controlling recruitment into benthic habitats in *Cancer pagurus*. In 1997 monthly changes in density of megalopea and early crab stages of *Cancer pagurus* were studied in shallow sublittoral cobble habitat off the south east coast of Ireland. These stages were found during a characterization survey of the decapod fauna in this habitat.

Megalopae and early benthic phase juveniles were collected, using SCUBA diver operated suction sampling, on a number of occasions between June and November. Sampling was conducted at a chart depth of 7 m, in Saltees Sound, Co. Wexford, Ireland. The substrate sampled consisted of a mixture of sand, shell fragments, and small stones covered by approximately 50–70 % large stone. Algae cover was variable, normally consisting 40–80 % *Laminaria* sp. The decapod community was dominated by *Pisidia longicornis*.

The size of first stage crab ranged between 2.2–2.7 mm carapace width. Modal progression of the cohort and growth increment data indicated that settling juveniles attain a carapace width of approximately 5–7 mm in the first summer of growth. Molt increment approximated to a 27–29 % increase from pre-molt carapace width. The magnitude of size increment at molt was smaller after the first molt. Molt increment for individuals held in aquarium with a carapace width 8–40 mm ranged between 22–24 %.

The average maximum density of *Cancer*, 23 individuals m^{-2}, was observed in late August, at the end of the settlement period and before extensive loss of the new cohort occurred. The highest density recorded during the study, on the 7th August, was 44 individuals m^{-2}. Of this number, 28 individuals could be identified as young of the year.

Maximum density of first stage benthic juveniles occurred between late July and early August. The number of first stage crab decreased significantly after this period, corresponding to an increase in abundance of crab in subsequent size classes. The growth of first stage crab accounted for the occurrence of these larger individuals, but from the numbers observed it was evident that the proportion of crab entering subsequent instars rapidly decreased. As it seems highly unlikely that recently settled crab, of such small sizes would undergo any form of large scale movement, the observed decreases in abundance of newly recruited crab was probably due to mortality.

The largest individual caught during 1997 sampling measured 80 mm carapace width. Crabs above a carapace width > 40 mm never constituted more than 19 % of the total monthly catch. Crabs of this size where also absent from > 50 % of the sampling efforts. Larger juveniles may therefore be migrating from this habitat, perhaps into deeper water.

Megalopae and early crab stages of *Cancer pagurus* were found in cobble habitat in shallow water during this study. As only one type of substrate was sampled the substrate preferences or habitat requirements of these early benthic stages *of Cancer pagurus* is still unknown but is the subject of current study. The mechanisms controlling the apparently high mortality of settlers and early crab stages is likewise unknown but is likely to be an important determinant of recruitment to the fishery.

There is excellent potential in the application of suction sampling methods and settlement tray deployment to gather detailed and informative data pertaining to the spatial distribution and timing of settlement, and the processes effecting subsequent growth and survival of juvenile *Cancer pagurus*. These methods can also be used to provide an index of recruitment success and its inter-annual and spatial variability. If correlated with fishery performance, using an appropriate time lag, these indices can be a valuable fishery forecasting tool. These recruitment indices and forecasting methods have been developed for the Australian western rock lobster (*Panulirus cygnus*) and for the American lobster (*Homarus americanus*).

A paper on the interaction between the inshore fisheries for crab *Cancer pagurus* and whelk *Buccinum undatum* (Fahy, 1998) was presented and is summarized below:

The edible crab (*Cancer pagurus*) is captured on the south coast of Co Wexford for human consumption (its products being whole crab and crab claws) and to provide bait for the whelk fishery in the south west Irish Sea. The fishery appears to have been incompletely documented and indications are that in recent years landings from a short stretch of coastline (about 150 km) have exceeded 450 t annually. Most of the crab bait used in the whelk fishery, whose landings recently exceeded 6,000 t, is believed to originate in this area also and it is estimated at 7 % by weight of whelk landings, which is approximately 420 t at the peak of that fishery. The number of boats fishing crab on this coastline has increased from 45 a decade ago to 65 this year. Total fishing capacity/effort has risen by 128 % while that of an individual fisherman has risen by 80 % in the same period. Crab bait is obtained as discards from the claw fishery but examination of baits indicates that a large proportion of them consists of undersized crab from which the claws have not been removed. The average live weight of bait crab is 333 g while that of whole crab landings is 671 g. In spite of rising fishing effort the CPUE expressed in terms of kg per creel or weight of consignment delivered to buyer appears to be stable over the past five years.

Investigations on the efficacy of crab as a bait for whelk suggest the yield is not dramatically better than that attracted by dogfish *Scyliorhinus* sp or whitefish (haddock) offal although in combination with one or other of these the yield of whelk (measured in numbers) greatly increases. There is an unconfirmed suggestion that whitefish attracts smaller whelk than crab.

2.1.4 Edible crab in Sweden

Edible crab, *Cancer pagurus*, is the only crab species of commercial interest in Swedish waters (Hallbäck 1998). The distribution is from the Norwegian border to the northern part of Öresund, where the low salinity is the limiting factor. There are also strong stocks on the banks between Sweden and Denmark. The crab fishery is documented from the end of the 19 th century when crabs were exported to Denmark, Germany and Holland. There is no fishing during winter (December to May) when the water temperature and activity among crabs are low. The main annual fishing season usually start in July and ends in November. There are two categories of fishermen that catch crabs in Sweden: commercial and sparetime fishermen normally using various types of traps, 75 to 100 traps per fisherman, baited with fresh fish. During the last 20 years, a specially strong net has been used in long lines of 1 to 2 km., particularly on banks where the bottom is smooth during periods of 3 to 5 days. Recently, a special fykenet was also used in long lines fishing for periods up to 7 days. Fykenets are becoming more and more popular because of the valuable by-catches of lobster, eel, cod, ling, catfish and sole.

There are very few regulations in the Swedish crab fishery. All traps must have two circular escape openings with diameter of 75 mm. The reason for this is mainly to separate crab traps from lobster traps which must have smaller escape gaps. No minimum landing size and no trap limitation in term of number have been implemented at the present time for the commercial fishermen. Sparetime fishermen can only use 6 traps, one net of 180 m length or 6 fykenets. From 1950 up to 1970 landings averaged around 150 t. There was a drastic drop in the landings thereafter (below 100 t) probably due to massive importation of crabs from Shetland, Scotland and Ireland with competitive prices. Sweden imports around 1000 t per year at the present time. There is no processing industry in Sweden which means that all landings go to the fresh market.

2.1.5 Edible crab in England and Wales.

In England and Wales, there major fishery for edible crab is in the Channel, especially the western Channel. Smaller fisheries occur along the North Sea coast, and in south-west Wales (Figure 6, in Bennett, 1995). Total landings of edible crab in England and Wales increased from 2500 t in 1965 to a peak of 10220 t in 1990, before falling back to just above 8000 t in recent years. Different trends have occurred in the different fisheries as follows:

i) English landings from the Channel rose from 750 t in 1965 to 5800 t in 1984 as a result of a major extension of crab fishing onto offshore grounds in the western Channel during this period. After 1985, landings stabilised between 4000 and 6000 t, a progressive decline in landings from the western Channel being compensated by an increase in landings from further east.

ii) Along the North Sea coast landings decreased from 2500 t in 1960 to 1150 t in 1974, then returned slowly to 2200 t in 1987, before reaching a peak of 2000 to 4000 t between 1990 and 1995. North of the Humber, landings have declined progressively since 1960, but between the Humber and East Anglia landings have increased, especially from the new offshore fishery.

iii) On the west coast, landings increased from 100 t in 1975 to 600 - 800 t between 1989 and 1995.

These trends in landings are based on statistics collected from the principal ports, and they may well be underestimates because of unrecorded landings at small ports, or directly into France.

The edible crab fisheries are seasonal. In the Channel, landings are predominantly of female crabs caught in the second half of the year, with smaller landings of male crab caught in spring. Along the North Sea coast, the main crab fishing season is usually in late spring and early summer, but the new offshore fishery has extended the catching season through the summer (mainly male crab) into the autumn (females). These seasons correspond to seasonal changes in catchability associated with the recruitment, reproductive and migration cycles.

The main features of edible crab biology are summarised by Bennett (1995). For the North Sea coast stocks, the main biological and fisheries studies were published between 1967 and 1992 (various papers and reports by Edwards, Hancock, Edwards and Hancock, Addison and Bennett, as listed in Bennett, 1995). Biological studies and assessments for the Channel were published between 1974 and 1988 (various papers and reports by Bennett, Bennett and Brown, LeFoll, Latrouite and Le Foll, Latrouite and Morizur, as listed by Bennett, 1995). Bennett (1995) also summarised work on larval development (Nichols *et al.*, 1982, Thompson and Ayers, 1988) and on the distribution of zoea in the Channel (Thompson and Ayers, 1987, and Thompson *et al.*, 1995) and along the North Sea coast (Nichols *et al.*, 1982). These studies represent the main sources of information on the edible crab life cycle, distribution, migration and growth in Britain and France. Many of the results are derived from data obtained during the 1960's and 1970's.

Over-wintering ovigerous females hatch their eggs from May to July, after which post-ovigerous females begin to feed and become vulnerable to capture. When in the soft-shelled state they are presumably also inseminated, because in the Channel most females caught in the main autumn fishery contain well developed ovaries, and have a high meat content. Later in the autumn and early winter the eggs are extruded, and the females can no longer be caught in traps. It is presumed that they become dormant in the substrate, but there is little or no specific information about the location of the main assemblages of over-wintering females in this dormant state. Tagging results indicate that in the Channel the main autumn fishery coincides with the westward migration of spawning females, but the published data do not show whether individuals undertake this migration only once, or whether there is a regular return, and they do not show whether the migration pathways are diffuse or concentrated. Males show some westward movements but are more nomadic than females. In the summer, zoea can be found throughout the Channel and the western Approaches, but, curiously, in the most recent surveys (Thompson *et al.*, 1995), the highest densities of larvae occurred near the Straits of Dover, far away from the main crab fishing area in the western Channel. Along the North Sea coast, larvae are widely distributed between the Tyne and East Anglia, including the area of the new offshore fishery off East Anglia, where catches are dominated by ovigerous females in autumn in a similar way to the western Channel. Historical tagging results show that the principal direction of migration along the North Sea coast was northward, but these results were all based on crabs tagged close to shore, and the movement of crabs in the new offshore area has not yet been investigated in detail. The relation between spawning and nursery areas is not properly established in any of the fishing areas round Britain, although in French waters Latrouite and Le Foll (1989) found juveniles intertidally and in shallow inshore waters, whilst along the North Sea coast *Cancer pagurus* smaller than 30 mm carapace width (CW) have recently been found in suction samples collected at 5 to 10 metres depth in inshore waters in 1997 (Bannister and Lovewell, pers comm).

For growth, the available information is based mainly on moult increment and moult frequency data obtained from previous tagging studies. There appears to be little variation in moult increment between areas, but differences in moult frequency between the sexes and between areas result in significant differences in overall growth rate, which strongly influence the results of assessments. The smallest size of ovigerous female varies from 115 to 129 mm CW in the North Sea, and up to 133 mm in the Channel. Fecundity is high, varying from 0.25 to 3 million eggs, according to the size of female.

The above summary shows that although there is a reasonable understanding of the main features of edible crab biology and life history round Britain, there are still substantial gaps, and much of the previous work should be updated. In particular, the lack of information about the links between migration, spawning grounds, and juvenile areas, hinders our interpretation of stock structure, whilst recruitment studies are handicapped by the absence of data on the distribution and abundance of juveniles.

Large parts of the sea-bed in the North Sea between the Humber and East Anglia, and in the eastern Channel between Hastings and the Isle of Wight, are underlain by gravel which is much sought after for building purposes. These areas also coincide with locations where crab fishermen catch mature female crabs in autumn, and crab fishermen are therefore concerned about the possible impact of gravel extraction in these areas on crab fishing and crab stocks. Fishermen allege that dredging can interfere directly with crab fishing activity; could disturb migrating or over-wintering ovigerous females, whether by noise, or by sand washed out from the hoppers; and could render the ground unsuitable for future spawning by changing the topography. Long term, these effects might reduce spawning stocks. Before production licences are issued for gravel extraction areas, the Environmental Impact Assessments required by UK gravel licensing procedures are used to assess the likely seriousness of these possible effects in individual areas, and to advise on possible zoning and mitigation measures. These assessments are handicapped at present by the lack of detailed knowledge about the location of sites for over-wintering dormant females, the likely reaction of migrating and dormant ovigerous female crab to noise and sanding, and the identity of those spawning areas most critical to crab recruitment. Scientists at CEFAS Lowestoft are currently investigating the offshore crab spawning ground off East Anglia, and monitoring the catch rates of crab fishing off Hastings in the eastern Channel, in order to improve our understanding of this problem.

2.1.6 Spider crab in Spain

Different aspects of the biology, life history and fishery of the spider crab *Maja squinado* have been studied in Galicia (NW Spain): growth, terminal molt and sexual maturity (González-Gurriarán *et al.* 1995; Sampedro *et al.*, submitted); reproductive biology and mating (González-Gurriarán *et al.* 1993, 1998); habitat selection and migrations (González-Gurriarán & Freire 1994a, b; Hines *et al.* 1995; Freire & González-Gurriarán 1998); feeding (Bernárdez *et al.*, submitted); epibiosis and its relationship with the phases of the life cycle (Fernández *et al.* 1998; Parapar *et al.* 1998); and the relationship between the life history and the fishery (Freire *et al.*, submitted).

Postlarval settlement of *Maja* occurs from late spring to autumn, and juveniles mainly inhabit shallow (< 15 m) rocky and sandy areas presenting restricted movements. Juveniles, during their last grow year, show 1 to 3 molts (mode = 2) with a percentage of size (carapace length, CL) increment at molt of approximately 20 and 40 % (average 32 %, representing approximately a 90 % increment in body weight). Juveniles attain sexual maturity after a terminal molt that takes place in summer, when crabs are 2+ years old. The size at onset of sexual maturity (define as the CL where 50 % of crabs attain maturity) is 132.7 mm in males and 130.4 in females in the Ría de Arousa (southern Galicia). Recent findings indicate that size at maturity could vary spatially and temporally, with larger sizes in northern areas of Galicia (unpublished data)

Post-pubertal adults carry out an autumn migration to deep soft bottoms (approx. 40 to 100 m) associated with the development of seminal receptacles and gonad maturation in females. The start of the migration coincides with the beginning of a drop in water temperature and salinity in shallow waters, due to a change in the oceanographic and meteorological conditions. In January and February, following mating, a return migration to shallow waters usually occurs in females, to incubate the first annual brood. This migration could reduce the duration of the incubation and facilitate the recruitment in appropriate habitats.

The annual breeding period of *Maja* ranges from March until November, and the number of broods a year per primiparous female is estimated to be three, with hatching occurring from May to November. Mating occurs in the wintering habitats, mainly in January and February, when females have gonads in an advanced maturation stage.

2.1.7 Velvet Swimming crab in Spain

The available data about the biology and life history of the velvet swimming crab *Necora puber* in Galicia (Spain) comes from studies carried out with populations inhabiting mussel raft culture areas. In this habitat, the velvet swimming crab uses the food and habitat provided by the culture. Existing information comprises aspects such as growth and sexual maturity (González-Gurriarán 1981a; González-Gurriarán 1985a; González-Gurriarán & Freire 1994); reproductive biology (González-Gurriarán 1985b); feeding (González-Gurriarán 1978; Freire & González-Gurriarán 1995); embryonic development and larval biology (Alvarez-Ossorio *et al.* 1990; Mene *et al.* 1991; Valdés *et al.* 1991a, b); performance of traps (González-Escalante & González-Gurriarán 1984); and population dynamics of the exploited stock (González-Gurriarán 1981b). An important point is the urgent need to redress the lack of studies in rocky areas, the characteristic habitat of this species.

The velvet swimming crab attains the sexual maturity at the age 1+, with a carapace width of 53.3 mm in males and 52.3 mm in females based on morphometric criteria, and 54.8 and 49.8 mm, respectively, based on reproductive criteria. The growth rate (percentage size increase at molt) decreases with increasing body size, ranging from 31 to 10 % for crabs with carapace width from 15 to 73 mm. This species shows a clear annual reproductive cycle with two broods in January and April. Fecundity increases with body size, from approximately 35000 to 450000 eggs per brood in females with sizes from 47 mm to 90 mm.

The influence of temperature and salinity on the embryonic development and larval biology has been analyzed in laboratory experiments. The duration of the incubation ranges from 41 days at 15°C to 18 days at 25°C, and the larval development from 49 to 28 days at these temperatures.

2.2 Crab fisheries in Canada

Most of the fundamental biology of snow crab (*Chionoecetes opilio*) have been described in the two previous reports of the Study Group. Old and new insights are summarised as follows (Dufour and Sainte-Marie 1998). Females mate in late winter or in spring and carry the fertilized eggs under the abdomen for one two years, depending on the ambient water temperature. After hatching in spring, the larvae go through a planktonic stage for three to five months, and then metamorphose into small crabs and settle on the sea bottom in the fall. It takes at least nine years after hatching for a male crab to reach the legal size of 95 mm. Since molting occurs in spring, the males available to the spring fishery are at least ten years old, whereas those available to the fall fishery may be only nine. In both sexes, growth ceases after a "terminal" molt, with females reaching a final size of 35 to 95 mm and males 38 to 165 mm. Females and males do not live much longer than five to six years after their terminal molt. Snow crab populations of the Estuary and northwestern Gulf of St. Lawrence exhibit abundance fluctuations which comprise an eight-year sequence, which includes at least three consecutive age classes with low abundance, collectively designated as a "recruitment trough", and up to five consecutive age classes consisting of a moderate to large number of crabs, collectively called a "recruitment wave".

The influence of environmental change has been studied by Sainte-Marie and Gilbert (1998), who showed that water in the ICL (Intermediate Cold Layer) of the Gulf of St. Lawrence was cooler than usual after the mid 1980s and covered a larger part of the Gulf seabed. Major consequences for snow crab were:

1. In crabs exposed to colder water, growth slows down and terminal molt occurs earlier than in crabs exposed to warmer water temperatures (2–3 °C).

2. In cold periods, areas suitable for crab are more extensive, since cold water is in contact with a larger part of the seabed.

   Thus in the northern Gulf of St. Lawrence snow crab populations, the 1980–84 year-classes, which contributed heavily to the fishery between 1990–94, were born in a period when water was relatively warm. They enjoyed good growth and then benefited from the extensive habitat available as the Gulf cooled. This may explain their excellent productivity.

   In contrast, the 1988–92 year-classes were spawned in very cold conditions, and many of the males of the 1988–89 year classes have undergone their terminal molt at a very small size, with the consequence that fewer males reached the commercial size.

3. Egg production may have declined during the cold period owing to a shift from a 1 year to a 2 years duration for egg incubation:

- Studies of reproductive patterns of female snow crabs reported:

Studies	Incubation Time (months)
Baie des chaleurs (1989–90)	24
Baie Ste-Marguerite (1991–92)	24
Baie Ste-Marguerite (1996–97)	12
Same areas (1969; 1982–83)	*12*
Northwest Pacific (beginning and end 1980s)	*12 to 24*

2.2.1 Newfoundland snow crab

Newfoundland Snow crab (*Chionoecetes opilio*) landings reached 45,903 t in 1997, an increase of 20.8 % over the previous year. The fishery is concentrated along the northeast and southeast coasts of Newfoundland and Labrador with a small, inshore fishery, inaugurated in 1995 operating in nearshore areas of the island. The fishery is prosecuted by several fleet sectors; these include full-time, large supplementary (> 40 gross tons), small supplementary vessels (< 40 gross tons) and vessels under 35 ft. In 1997 approximately 3100 licenses were issued to Newfoundland and Labrador fishers. Vessels are licensed by NAFO division boundaries and are restricted to fishing snow crab management areas within their division. Each year, before fishing activity commences, Resource Management Branch issues a Snow Crab Management Plan which outlines quotas per fleet sector by management area, trap limits, seasons etc. and describes intra-area boundaries which serve to segregate fleet sectors.

Assessment of fishery performance for each of the various management areas relies on analyses of fishers logbook entries (mandatory for all fleet sectors) as the principle means of comparing a given years fishery performance to that of the previous fishing season. The standard used in this comparison is catch per unit of effort (CPUE) calculated by dividing the landings for a trip by the number of traps hauled, as reported in the log books. While information obtained from most logbooks during the course of a fishery is reasonably accurate, providing reliable data on catch and effort, some management areas are problematical in terms of interpreting the information provided.

Changes in CPUE from one year to the next may not accurately reflect abundance due to, for example, environmental effects (water temperature), changing fishing patterns, changes in fishing season etc. Comparison of 1995 and 1996 CPUE data was particularly problematical for several reasons. In 1996 a two-tiered pricing system was introduced whereby fishers were paid a higher price for crabs greater than 102 mm carapace width. Also in 1996, a harvesting strategy which assigned individual quotas to fishers was applied to all fleet sectors. These factors led to extensive high-grading in all areas except Labrador. In NAFO Division 3LNO fishers in offshore areas increased the mesh size of a large proportion of their traps. These factors could have artificially reduced CPUEs in comparison with 1995 catch rates. In 1997 the fishery was delayed in opening due to a price dispute. This meant that much fishing activity was carried out during the hottest time of the year. The additional culling encouraged by the two-tiered price system carried out during the hot summer months rather than the cooler spring may have contributed to higher than average discard mortality for a second year in a row.

Landings and effort increased over 1996 levels in all NAFO Divisions except Labrador (2J) where effort declined slightly. Logbooks have also been utilized to determine fishing positions of crab fishers with the aim of summarizing fleet fishing patterns, identifying portions of the fishing grounds that are the most heavily fished, delineating the boundaries of new fishing grounds and illustrating the expansion of the fishery in recent years both in terms of effort and area. A large sub-sample of the log book entries of full-time and supplementary fishers are entered into a computer data bank to produce a computer-generated map of Newfoundland and Labrador indicating these fishing positions. To date, charts have been produced for the 1994, 1995 and 1996. We are continuing with plans to produce a full retrospective set for the period 1979–96 inclusive. Currently data are available for the period 1990–97. In recent years there has been an increase in the reported incidence of snow crab infected with Bitter Crab Disease (BCD), a condition caused by a parasitic dinoflagellate which invades the body of recently molted crabs. Although the parasite is harmless to humans, crabs infected by it are all killed and their flesh is inedible. The disease appears to be spreading and is particularly evident in NAFO Division 3K.

2.2.2 Southern Gulf of St. Lawrence snow crab

The snow crab fishery in the southern Gulf began in mid-1960s (Hébert and Moriyasu 1998). There are three fishing areas: 12/25/26, 18 and 19, and two exploratory zones (E an F) each with separate management schemes.. Area 12 (biggest Area) was traditionally fished by 130 fishermen from New Brunswick, Quebec and Nova Scotia. The fishery expanded rapidly, and landings peaked in 1982 at 31,500 t. Landings then fluctuated around 25,000 t until 1986, falling to 11,700 t in 1987. In 1989, the fishery was closed due to a high incidence of soft-shelled crab. The quota was set at

7,000 t in 1990. In 1995, landings were 19,944 t (quota of 20,000 t) and 4,500 t was allocated for the first time for one year to 131 non-traditional vessels. Areas 18 and 19 (Cape Breton Island) were fished for the first time in 1978–79 by the inshore fishermen of Cape Breton. Quotas have fluctuated around 600 t and 1,400 t in each specific Area since.

In 1996, the Southern Gulf of St. Lawrence (areas 12–25/26, 18, 19, E and F) snow crab quota was set at 16,100 t of which 3,508 t was allocated to 123 non-traditional vessels. In 1997, the southern Gulf portion of Area 12 and Area 25/26 were integrated to form one management unit. The 160 traditional fishers were allowed a total quota of 13,100 t and 2,290 t was allocated to 93 non-traditional vessels.

In 1995, exploratory fisheries were conducted for the first time in Zone E (4 vessels and a quota of 217 t) and Zone F (7 vessels and a quota of 317 t). Parts of these areas had been fished in the past by the traditional fleet. These fisheries were maintained in 1996 with lower quotas of 164 t and 238 t shared by 8 and 14 vessels respectively. In 1997, the quotas were 163 t for Zone E and 288 t for Zone F shared by 8 and 16 vessels respectively.

In 1996, the quota for the Prince Edward Island fishery (Area 25/26) was set at 750 t of which 600 t was reserved for the 30 traditional permits and the remaining 150 t was to be allocated to the non-traditional permits holders. Due to the foreseen declining stock condition, after the 600 t fished by the traditional fleet, the 150 t was not allocated to the non-traditional fleet. In 1997, the 30 traditional fishers from P.E.I. (Area 25/26) were given access to Area 12 using a maximum of 50 traps per license.

In 1996, the quota for the Area 18 off Cape Breton fishery was set at 340 t to the 30 traditional fishers and no temporary licenses were issued. The season was closed early due to a high incidence of soft-shelled crab and low catch rates. In 1997, the quota was set at 580 t. The fishing season was prematurely closed for a second year due to the high incidence of soft-shelled crab and low catch rates. The 1997 landings were 406 t which correspond to 70 % of the total quota.

In 1996 and 1997, the quota for the Area 19 off Cape Breton were set at 1,343 t and 1,386 t respectively for the 111 traditional license holders.

2.2.3 Northern Gulf of St. Lawrence snow crab

The snow crab fishery in the Estuary and northern Gulf of St. Lawrence began in the late 1960s (Dufour and Sainte-Marie 1998). From 1968 to 1971, vessels from Quebec and New Brunswick reported catches of about 1000 t from around the Port Cartier sector of the Middle North Shore. Then, a limited inshore fishery took place, with annual landings of roughly 200–300 t until the late 1970s. The fishery experienced a boom from 1979 to 1985, when the number of participants, fishing effort, geographic extent and landings increased substantially. Between 1987 and 1989, landings for the entire region of the Estuary and northern Gulf of St. Lawrence fell from 5,255 t to 2,622 t. This fall was accompanied by marked decreases in catches per unit of effort and ever greater catches of white crab, as a direct result of a recruitment trough affecting the 1977–1979 age classes. Beginning in 1990–91, the white crab problem gradually disappeared, catches per unit of effort rose, and landings increased to a record level of 7,245 t in 1995, due to the incoming recruitment wave made up of the 1980–84 age classes. Landings fell slightly in 1996 (6,716 t) and 1997 (5,499 t) as a result of the decrease in total allowable catches in all areas and the inability of some fishermen to reach their 1997 quota.

2.2.4 Rock crab (Cancer irroratus)

The fishery for rock crab (*Cancer irroratus*) is relatively new in the Gulf of St. Lawrence (Gendron 1998). It started in 1974 in the southern Gulf of St. Lawrence. The fishery started later (1988) in Quebec and closed after only 2 exploitation years mainly because of a fall in the market price, then resumed in 1995.

Fishery management is actually based on the following characteristics:

- Males only fishery;
- Entry is limited;
- Male size limitation (over 102 mm CW);
- Traps are limited and selective to avoid lobster;
- Landings are limited in certain areas

It is a developing fishery with relatively low landings (around 350 t in 1995). As the species cohabit with lobster, impact on the exploitation of lobster is carefully managed.

3 ASSESSMENT METHODS USED ON CRABS

3.1 Snow crab in Canada

In the southwestern Gulf of St. Lawrence a post-season trawl survey has been conducted since 1988 using a Bigouden *Nephrops* trawl, with a 20-m head line opening, a 27.3-m foot rope on which is mounted a 3.2-m galvanized chain (8 mm). A stratified-random survey is used: one or two locations are randomly chosen among 9 squares within each 10 min. by 10 min. longitude-latitude rectangle. To minimize interannual variation in catchability, the same stations, vessel and trawl net have been used since the beginning of the survey. In 1988, there were 173 stations in the southwestern Gulf of St. Lawrence (Area 12) but starting in 1990 the survey was extended to all areas in the southern Gulf of St. Lawrence with a total of 262 stations.

The duration of tows varied between 5 to 8 minutes at a mean speed of approximately 2 knots depending on the depth, current speed and sediment type. The duration of each tow and the depth of water column are recorded. The horizontal opening of the trawl has been measured with a SCANMAR system. The distance of each tow was estimated from the position (latitude-longitude) measured at the start and end of the tow. The swept surface was then calculated based on the distance and the net width measured by every 7 seconds by the SCANMAR distance net sensor.

All male crab were measured for carapace width and claw height using a vernier caliper, for carapace hardness using a hardness gauge, and for carapace condition (categorized into five groups). Size frequency histograms were standardized to the surface area swept by the trawl.

A geostatistical method, kriging is used to estimated annual biomass and to map density contours of different categories of crab. Kriging consists of two procedures: 1) analyzing and modeling the covariance between sampling units as a function of distance between their locations and, 2) calculating optimal weights to be attributed to each sampling unit. Separate variograms and density estimates are made for each sampling unit using block kriging, then summed to a total surface of 36 931 km2 for the southern Gulf of St. Lawrence.

The abundance of snow crab estimated by kriging is converted into biomass using a size-weight relationship and size frequency histograms. The size-weight relationship for adult hard shelled males is expressed by the function: $W = 2.665 \times 10^{-4} CW^{3.098}$. Natural mortality and movement between the survey and the fishing season 6–7 months later are considered to be negligible.

Estimates were made for: 1) The total commercial biomass available to the fishery in the following fishing season. The biomass of adult males ≥ 95 mm hard (residual biomass) and soft-shelled (new recruits); 2) The abundance of adolescent males ≥ 56 mm which molt the following year at carapace sizes larger than 70 mm and will be catchable by traps during fishing activity.

Trawl surveys appear to be an appropriate method for assessing stock abundance and recruitment, and geostatistics appears to be an appropriate method to describe the patchy distribution of snow crab. Multivariable co-kriging techniques can be used to take into account the effect of environmental variables such as sediment, depth and temperature on the abundance and distribution of snow crab.

For the Northern Gulf of St. Lawrence snow crab, three types of information are used to assess the snow crab populations:

1. Fishery statistics, mainly log-book data from the fishermen and sale slips data from the industry. Landings, CPUE and Fishery effort for a given year can be calculated and compared thereafter retrospectively. Catches are sampled regularly at sea and at ports to follow the demographic structure of the populations through time. This began in 1983 in the northern Gulf.

2. Research surveys undertaken annually with a beam trawl. Sampling is done in specific areas of the northern Gulf of St. Lawrence believed to be representative of the snow crab populations living on the territory. Long term abundance indices (densities or total abundance) for different categories of crabs (pre-recruits, recruits, residual biomass, immature, primiparous and multiparous females) and crabs of different conditions (before and after terminal molt) have been calculated since the end of the eighties.

3. Research surveys done with commercial crab traps during or after the fishing season. This type of survey is a joint venture with the fishermen who carry out the field work, and DFO biologists who do the planning and the analysis of

the survey data. Valuable short term abundance indices have been calculated since 1994 in certain areas, for different categories of crabs and will serve to adjust the yield on a long term basis. Anecdotal information is also included in the analysis when available.

Newfoundland snow crab research vessel surveys are conducted annually in three snow crab management areas in NAFO Division 3L; Northeast Avalon (6C), Bonavista Bay (5A) and Conception Bay (6B) and since 1994 in White Bay (3B) in Division 3K. The surveys are carried out using both commercial crab traps (in order to emulate those used in the commercial fishery), and small-meshed traps. Traps are set at randomly selected stations stratified by depth, and weather permitting, traps are hauled after a 24h soak and sampled in order to determine catch per trap, size frequency, shell condition, and the proportion of small-clawed males (potential recruits). In 1996 bottom trawling with a modified shrimp trawl was initiated in all 4 survey areas. Tows of 10 minutes duration were made at a speed of 2.5 knots. Catches were sorted according to sex and sampled in the same manner as were trap-caught crabs. In 1997 the number of traps per fleet was reduced to 8 in order to free up more time for trawling activities. In recent years, it has been observed that there had been a steady decline in the proportion of small-clawed crabs in all areas which may indicate a downward trend in recruitment. This phenomenon was be monitored closely during 1997 research surveys by means of both small-meshed traps and the modified shrimp trawl. It appears that the decline in the proportion of small-clawed catches may have bottomed out as their abundance in all areas increased slightly in 1997.

3.2 Spider crab in Spain

The fishery for *Maja* targets both males and females. The fishery on the coast of Galicia (NW Spain) mainly involves a tangle-net fleet that operates throughout the distribution area of the spider crab, and artisanal fleets in specific geographical areas that use the glass-box (in shallow habitats) and traps. Most of the catch is the result of the tangle-net fishery, which depends directly on the activity of the crabs, and particularly on their directional movements or migrations.

The open season for the *Maja* fishery in Galicia is between November-December and May-June, depending on the year and the geographical area. The seasonality of the catches is similar all over the Galician coast. The port of O Grove (Ría de Arousa, southern Galicia), the most important port in the area, accounts for approx. 30 % of the total catch in Galicia. Most of the catches in this port are obtained during the initial stage of the fishing season, which coincides with the start of the migration period. Thus, during the open fishing season 60–80 % of catches are made during the first 10 weeks. Before the fishing season officially opens (from September to November), a presumably large amount of catches are taken, which would mean that the fishing rate of the stock during the initial stage is probably even higher.

Different methods have been used to estimate the fishing mortality throughout a fishing season and they all result in high mortality values with a mean mortality rate per fishing season of 91 %. The exploitation of *Maja* in Galicia depends, for the most part, on the annual recruitment of the crabs that reach sexual maturity in the summer and start their migration in autumn. Each cohort is cut by over 50 % in the first two months of fishing and by over 90 % by the end of the season.

As a result of fishing mortality, over 90 % of the adult population of *Maja* on the coast of southern Galicia is made up of crabs that reached sexual maturity during the preceding summer; therefore the reproductive success of the population depends on the annual recruitment. A comparison of the seasonality of the life-history events and of the fishery shows that less than half of each cohort will have the opportunity to mate in the winter habitats, due to the depletion of the stock caused by the fishery. Females that survive the fishing season will be able to hatch an average of 3 times, but only a small percentage of the population (less than 10 %) will achieve this reproductive success.

The present management regulations for the spider crab fishery in Galicia include: 1) a minimum landing size (120 mm carapace length excluding frontal spines), 2) protection of ovigerous females, and 3) a closed season (from 1st June to 1st November in the southern area, and from 1st July to 1st December in the northern area).

3.3 Edible crab in England and Wales

Crab fisheries in Britain are monitored by collecting landing statistics, and sampling the size distribution of landings quarterly, at the principal ports. Published assessments are those of Hancock (1965, 1975), Bennett (1979), and Addison and Bennett (1992). Hancock (1965, 1975) used the Gulland (1961) method to evaluate the effect of minimum size changes on yield per recruit for a possible range of values of F and M. For the Channel fishery, Bennett (1979) estimated Z using growth estimates from tagging to decompose a length frequency catch curve into an 'age structure'. The most likely value of F was estimated at 0.45 for an M of 0.14. A yield per recruit model was then used to investigate the likely effect of changes in F and size at first capture for a range of M values. For the North Sea coast, Addison and Bennett (1992) investigated the effect of changes in effort and size at first capture. They analysed length frequency data using the length cohort analysis model of Jones (1981), coupled to a range of assumed stock and recruitment curves, and assumptions about M. Previous tagging data were used to calculate von Bertalanffy growth parameters. Fishing mortality on female crab ranged from 0.4 near the Scottish Border, to 0.6 north of the Humber, and 2.9 in East Anglia. The corresponding values for male crab were 0.6, 1.0, and 3.0. The length cohort analysis model shows that in these areas a substantial decrease in effort would be required to reduce the level of exploitation to F_{max} on the yield per recruit curve. The results for East Anglia reflect a size distribution which is very truncated, and may conceivably be biased by the absence of sufficient shelter for larger crabs, (Howard, 1980), which could cause additional natural mortality which is inappropriately assigned to F by the size-based method. There are at present no specific data on stock and recruitment for edible crab stocks in Britain.

The principal management tool for edible crab in Britain is at present the minimum landing size (MLS). The above length-based assessments were used to establish a sequence of national minimum landing sizes on a regional basis. In 1976 a single MLS of 115 mm carapace width (CW) was established for all areas in Britain. In 1986 the MLS in the Channel was raised to 140 mm CW for both sexes (eastern Channel), and 140 mm for females and 160 mm for males (western Channel). In 1990, MLS was raised to 130 mm CW for both sexes in South Wales, and to 125 mm elsewhere in the UK, except for Norfolk and the north-west coast of England, where 115 mm CW was retained. These regional differences reflect the influence of regional differences in growth rate, as well as local differences in the size composition of crabs available on the ground.

There is concern about the prolonged decline in edible crab landings north of the Humber, and from the western Channel, and it is widely alleged by fishermen that except where effort has spread to new offshore grounds, as in East Anglia, parts of the western Channel, and parts of south Wales, the catch per effort of edible crab in most of the established fisheries round Britain has been decreasing throughout the 1990's. Official data on crab fishing effort are inadequate, and make this difficult to verify, but a preliminary catch-curve assessment based on size composition data aggregated for the whole western Channel, and averaged for the period 1986 to 1995 (Bennett, pers. comm.) suggest that F is 0.94 for $M = 0.1$ (Anon. 1998). Although this assessment has yet to be validated, it indicates that F is now substantially higher than the value of 0.45 estimated by Bennett in 1979. New regional assessments of the stocks are therefore overdue, and work is in progress to summarise mean size frequency data for major ports in England and Wales for a series of years, so that up-to-date length-based assessments can be carried out. Data for 1995 to 1997 have almost been completed. *Force majeure*, these assessments will use historical growth data, and will aggregate geographically unstratified samples for large coastal areas independently of the underlying stock structure. Some sectors of the crabbing industry have called for restrictive licensing, and the results of the new assessment will be used to evaluate the case for this.

3.4 Others species

The fishery for the velvet swimming crab, *Necora puber*, in Galicia (Spain) is carried out mainly in subtidal rocky areas with traps and, to a lesser extent, in soft bottoms areas devoted to mussel raft culture with beam trawl. Some preliminary yield per recruit analyses of the soft-bottom fishery have been carried out (González-Gurriarán *et al.* 1981b). In the last years, a sharp decline in the catches of this species has been observed in Galicia, associated with a change in the closed season from spring-summer to winter-spring. The trap fishery targets both the velvet swimming crab and octopuses, and the change in regulation was due to pressure from fishers to increase octopus catches.

The present management regulations for the velvet swimming crab (*Necora puber*) fishery in Galicia include: 1) a minimum landing size (45 mm carapace length), 2) protection of ovigerous females, and 3) a closed season (fishery is open from 1st to 15 th January and from July to October/November).

4 CRAB PRODUCTION IN EUROPE TAKING INTO ACCOUNT THE FACTORS AFFECTING QUALITY

This subject was not well covered during the meeting because of a lack of information on certain species, so it should be included in the terms of reference of a future meeting of the group and covered in depth at that time. However, crab quality and meat content variations through time were discussed for edible crab (Tully and Cosgrove 1998). A similar document on snow crab was also available (Dufour *et al.* 1997).

4.1 Edible crab

After the molting season, meat content (muscle and hepatopancreas) of *Cancer pagurus* is extremely variable but cannot be objectively predicted by visual inspection of the crab. At this time of year large quantities of poor quality crab, containing very little meat, can be landed by the fishery. Although fishermen have little problem in discriminating the poorest or best quality crab the discrimination of crabs between these extremes is very subjective. The landing of poor quality crab is a problem for the following reasons:

1. Processing of these crabs in factories is uneconomical and increases processing costs overall;

2. Quality of live exported crab is variable and unpredictable and decreases the value of the product and customer perception of it;

3. The yield per recruit from the fishery, in terms of meat yield, is not optimized.

A solution to the problem would involve being able to identify poor quality crab at sea and discarding crabs that did not meet predefined criteria. These criteria could be defined by crab processing plants, by the market, or by fishery management that aimed to maximize the yield per recruit.

A meat content study was conducted on Edible crab in Ireland to find solutions to this problem (Tully 1998). Although not well studied, the molt cycle in *Cancer* involves extensive tissue degeneration and re-growth accompanied by extensive changes in tissue physiology and morphology. There is extensive muscle loss from the claws and body. During or shortly after the molt water is absorbed and the body is filled with a jelly like matrix for a period of time. This matrix is gradually replaced as new tissue forms. The time course and schedule of these events is not well described.

Observation of the length weight relationship in *Cancer* indicates considerable variation in weight at any given length. This within size variation in weight could be due to (1) differences in body shape or (2) to variation in the weight of the shell or internal tissues. The first possibility is unlikely although multivariate morphometric analysis of body shape in crustaceans does show changes associated with maturation. Within crabs of the same size only a proportion of the crabs may be mature and therefore body shape may be variable. However, this is unlikely to contribute to within size weight variation throughout the entire size range of crab landed by the fishery. The observation that recoverable meat content is extremely variable in *Cancer* suggests that weight of crabs of any given size may be determined by their position in the molt cycle and the amount of meat (muscle, hepatopancreas) they contain. This assumes that the density of tissue is higher than the jelly like matrix, which occupies the main body of the crab after molting, and therefore that tissue growth results in continuing increase in weight up to some maximum determined by the shell size.

Results also show that the position of a crab in the length weight relationship could be a useful indicator of the meat that the crab will subsequently yield. The data presented used brown (hepatopancreas) only. As the hepatopancreas is the crab's principle energy store it may not vary as greatly in weight during the molt cycle as other tissues such as claw muscle. Other tissues, in particular white muscle, may be more closely correlated with body weight at a particular size. Use of all tissues may therefore give a higher capacity to predict the meat yield using size and weight.

If the observed variations in weight are due to changes in tissue growth during the molt cycle, the data indicate that an individual crab may be caught and processed when it is only 60 % of its potential weight for that size. If all crabs were landed at their maximum potential weight then, simplistically and not accounting for natural mortality during recovery to maximum weight, the meat yield per recruit could be increased by 40 %. Confirmation and acknowledgment that the extensive variation in weight at any size is due to different meat content is therefore important. This would then enable criteria to be set that optimized either yield per recruit (at any desired % of the maximum possible) or to satisfy any particular market criteria.

If length and weight can be used to predict meat content then its application to the fishery will rely on being able to measure length and weight on board fishing vessels at sea. However, more data are required to confirm the relationship between weight at a particular size and the yield of different types of meat from crab including hepatopancreas, muscle and ovary. Furthermore, the contribution of differences in shell weight to the observed variation in weight also requires further study. The functions that best discriminate poor from good quality crab for a given set of criteria also need to be derived.

5 IMPACTS OF CRABS, PARTICULARLY INTRODUCED CRAB SPECIES, ON NEARSHORE COMMUNITY DYNAMICS AND BIVALVE MARICULTURE

Crabs are the dominant crustacean predator in the intertidal and, along with homarid and palinurid lobsters, are also a major crustacean predator in the sublittoral zone as well. While many larger crab species are economically exploited, their impact on prey species such as bivalves, many of which are also exploited, can be substantial. Where ecosystems contain solely indigenous species, relative abundance of prey and predator are in effective balance, and while individual species' abundance may fluctuate substantially over time for a variety of reasons, many of which are abiotic, the overall system is typically in a general equilibrium, allowing each species to maintain its presence and take advantage of unique opportunities to increase in abundance when it can. Humans have increasingly disrupted this natural ecosystem balance in the marine environment in a number of locations by the intentional, or accidental, introduction of exotic species. This has potentially significant implications for the whole ecosystem, but has tended to be most noticeable when it impacts local, commercially exploited species.

While humans have established many non-indigenous marine species world-wide, relatively few large, higher trophic marine species have been introduced into geographic areas where they did not previously occur naturally. Some intentional introductions have occurred, most being for anadramous species (e.g., salmonids), and a large crustacean, the North Pacific red king crab (*Paralithodes camtschaticus*) was successfully introduced to the Barents Sea. Benthic crustaceans which have become accidentally established elsewhere are the European green, or shore, crab, *Carcinus maenas* (Portunidae); the west Pacific shore crab, *Hemigrapsus penicillatus* (Grapsidae) (P. Noël, pers. comm.); the west Pacific shore crab, *H. sanguineus; Charybdis hellerii* (Portunidae); and the west Atlantic blue crab, *Callinectes sapidus* (Portunidae) (S. Khvorov, pers. comm.), to name a few. The Chinese mitten crab, *Eriocheir sinensis*, has also been introduced into many localities, including Europe many decades ago and San Francisco Bay, CA, in the early 1990s, but it is considered a catadromous crab, as adults only move to saline habitats to reproduce and then die. Here, we focus on the relatively recent introduction of the marine European green crab into the north-eastern Pacific, and review briefly how the species has colonized its new environment, how it is dispersing from its location of introduction, what perceived biological consequences have been detected to date, and what biological consequences might be expected if its range extends into the island waters of British Columbia and Washington State. It is suggested that this introduction should not be taken lightly, regardless of its ultimate impact, as it indicates the current ease with which potentially disastrous introductions can occur.

Because of its tolerance of a wide range of both salinity and temperature, the green crab is perhaps particularly likely to survive in many places throughout the world. This argument can also be made for most intertidal species, which are also adapted for relatively extreme environmental conditions. Ecosystem implications arising from establishment of exotic species are increasingly being recognized, with the very real threat that existing fisheries may be negatively impacted by exotics.

The European green crab is a medium sized (adults about 40–80 mm CW), intertidal brachyuran crab which is an extremely aggressive species reported to feed on a wide array of prey; over 150 genera of animals and plants. Species prey include numerous bivalves, other crabs, and conspecifics. Fish remains have been found in stomach samples, but whether these resulted from scavenging or capture of live fish is unknown. Green crab have remarkably broad physiological tolerances; they are euryhaline as adults down to 4‰ and as larvae to 17‰, and can overwinter in water temperatures to less than 0° C. The species occupies a diverse array of habitat from open sand/mudflats to shell, cobble and, and in the Atlantic at least, routinely makes diel and seasonal migration from sub- to intertidal zones. It typically migrates into the intertidal on the flood tide and retreats sublittorally on the ebb, although it is commonly found "stranded" between tides. Hence, its predominant impact as a predator is intertidal, but with a shallow sublittoral zone impact as well.

Green crab exert predatory control over species abundance and community structure, particularly on bivalves, and compete with and displace certain shrimp and crabs when. Although perturbations to fauna where green crab have been introduced have often not been well documented, its proliferation into Maine, USA, was coincident with extensive reduction in beds of the soft-shell clam *Mya arenaria*.

The documented physical limits to reproduction of green crab may provide clues to the sustainable limits of the ultimate distribution and range of the species in the north-eastern Pacific. While adult green crab are tolerant of low salinity environments, eggs develop normally at 10° C. only in salinities greater than 26‰. Even higher salinities are required at lower temperatures and brief temperature falls will kill high proportions of eggs. With respect to upper thermal limits determined that green crab held in impoundments at 14–26° C. would not breed. Based on environmental tolerances alone, Carleton *et al.* (in review) estimated that green crab have the potential to colonize suitable sheltered areas on the west coast of North America from the Aleutian Islands to Baja California. Finally, green crab, as the first portunid to establish in the north-eastern Pacific, might be pre-adapted to exploit presently vacant niches uniquely suited to the Family.

Jamieson *et al.* (in press) have summarized the ecological implications for the north-east Pacific. In June, 1998, the species was reported on the southern coast of Washington State in Willipa Bay, which means green crab have spread over 1000 km northwards in the 8 years since they were introduced into San Francisco Bay. The varied intertidal habitats and unique ecological diversity of British Columbia means that green crab invasion consequences can only be generally predicted. Potential intertidal prey in the Strait of Georgia/Puget Sound are likely to be particularly impacted, and given the extensive mariculture and commercial clam and oyster fisheries there, economic consequences may be substantial. The South African experience, following the introduction of green crab there in 1983 and their subsequent slower spread northwards into the Langebaan Lagoon/Saldanha Bay complex may provide a useful example of the types of impact on mariculture which may be expected. The other commercially exploited Pacific species likely to be impacted by green crab is Dungeness crab, *Cancer magister.* Although a larger species as an adult, juveniles of this species are small enough to be prey of green crab, and Dungeness crab occur in the habitat likely to be occupied by green crab, i.e., shallow sandy areas, such as estuaries and bays. The dynamics between these two species may ultimately determine how well green crab become established, and what its economic effect will be.

The timing of green crab introduction to British Columbia may be within the next few years through benthic range expansion, but might be sooner through ballast water transport of larval stages. If the consequences of green crab invasion are to be determined and documented, then intertidal studies in areas of interest should be initiated as soon as possible to provide required baseline data.

Research on the predatory characteristics of green crab before this species becomes well established in British Columbia or Washington is important for several reasons. First, it will give perspective on the degree of impact to the shellfish industry this species may cause, whether as extensive as might be assumed given the ecological and physiological plasticity of green crab, or much less due to refuge provided by life history, morphological aspects or agonistic behavior of potential prey species towards green crab. Second, it will alert concerned bodies to the need for other research on means of attenuating the impact of green crab in settings where green crab might be "managed" to at least some extent. There is increasing practice in Washington, for example, to modify intertidal habitat with materials like shell and gravel to improve production of bivalves or recruitment of Dungeness crab. If green crab actively select such habitat, either for refuge or high prey abundance, the practice of habitat modification may need to be altered. Indeed, on-bottom oyster culture itself may provide extensive habitat for green crab and if so, growers may need to consider a mixed response of alternate culture practices and different seasonal and life history stages of out-planting. These could include cultch placement in the field as early as possible for maximal growth before annual green crab settlement, or holding cultch in protected areas until spat are large enough to reduce their consumption before field placement.

The above example is from a European species introduced into the Pacific Ocean, Pacific crustaceans have already been introduced into the North Atlantic. I It may only be a matter of time before ecological change arises from such introductions, and researchers need to be in a position to document potential consequences if they occur.

6 BIOLOGICAL REFERENCE POINTS ON CRAB HARVESTING STRATEGIES ESPECIALLY THOSE IN RELATION TO THE ULTIMATE GOAL OF PROTECTING THE REPRODUCTIVE POTENTIAL OF THE SPECIES

6.1 Northern Gulf of St. Lawrence snow crab

The Study Group discussed the following information from papers by Sainte-Marie and Sévigny (1997) and Powles (1997).

The present snow crab management measures are not exclusive to snow crab and as for other exploited resources, the main goals are resource conservation (protection of the spawning capacity, and avoidance of resource waste) and attainment of sustainable social and economic benefits.

Conservation of snow crab is ensured by size limits (95 mm CW), prohibition of harvesting females, mesh and effort regulations (mesh size and number of traps limited), harvest limits (TAC), and soft -shell closure protocols (the fishery is closed if the number of white (newly molted) crabs exceeds 20 %).

Controls on the amount of snow crab harvested have sometimes been considered of secondary importance for snow crab conservation, because of the other measures. It has been suggested in the past that harvesting 100 % of the legal sized male component would have little effect because enough sub-legal males and females would be protected by the size limit or maintain population reproductive capacity.

Recent information suggest that removing too many legal-size large-clawed males from the population might have an impact on population egg production capacity. A study in Newfoundland indicated that, at a given size, fecundity of females in heavily exploited areas was 15–20 % lower than in unexploited areas (Taylor 1996). Because recruitment occurs in pulses, and females from a recruitment pulse mature sooner than males, abundance of females will peak several years earlier than that of large males so large changes in adult sex ratio can occur as a pulse moves through the population (Sainte-Marie *et al.* 1996). This is a natural phenomenon in snow crab populations but fishery removals of large-clawed males could accentuate these fluctuations, in which case there could be inadequate numbers of males to fertilize all females, possibly affecting population fertility.

Essentially 100 % of females have been observed to carry eggs over the wide range of abundance seen in the past two decades, despite apparent high exploitation rates perceived in some areas. Recent studies (Sainte-Marie and Carrière 1995) have shown that at temperatures around 0 °C, characteristic of the snow crab habitat, infertile eggs take several months to be shed or to become visibly different from fertile eggs, so samples taken soon (few weeks to few months) after the mating season could provide faulty information on fertilization rates. In 1992 for example, over 50 % of the multiparous females carried between 23 and 59 % infertile eggs in the St. Lawrence estuary (Carriere 1995).

Although the fishery may have little effects on the reproductive success of primiparous females, at high exploitation rates it has a potential to severely impact the reproductive success of multiparous females. Some experimental evidence suggests that multiparous female *Chionoecetes* are reticent or unwilling to mate with adolescent males and smaller adult males (Moriyasu and Conan, 1988; Claxton *et al.*, 1994; Paul and Paul, 1996). Selective removal of large males could lead to a reduction of OSR (operational sex ratio) for multiparous females which is proportional to fishing mortality (i.e., 35–60 %). The resulting sperm limitation at multiparous spawning would be particularly deleterious to the reproductive success of t larger, potentially more fecund females. Although the relationships between sex ratio and insemination rate remain to be tested in the laboratory, previous studies (Sainte-Marie and Lovrich, 1994; Sainte-Marie *et al.*, 1997; Sainte-Marie et Sévigny in prep.) tend to indicate that male snow crab are sperm minimizers or conservers and that sexual competition plays an important role for female reproductive success. There is some convincing evidence that sperm limitation occurs cyclically in both unfished and fished populations of snow crab. Thus, a constant exploitation rate for males may be an inappropriate measure for conserving reproductive potential. Management strategies based on the maintenance of a minimum OSR value may be more effective to this end. Nevertheless, precautionary management would require that the above factors be considered in establishing harvesting strategies for snow crab.

Adolescent male crabs are crabs of various sizes that are still capable to growth (have not yet molted terminally) and reproduce (reproducing organs well developed), while not having developed their full reproductive capability (bigger claws). Biologically it would be desirable to protect adolescent crabs since their considerable growth potential (especially in weight) could help to damp future population fluctuations due to recruitment pulse. There would be significant difficulties in making the protection of adolescent crabs mandatory at this moment, however, Inexperienced fishers might not recognize them well and it might be difficult to develop a gauge sufficiently precise to be used for enforcement purposes. Sorting the catch for adolescents to discard might increase total sorting time so that discarding of soft shelled and undersize animals would be delayed, increasing mortality on those fractions. Also, regularizing discarding of legal-size adolescent animals might be seen as increasing opportunities for discarding of old-shelled animals (high-grading) which is undesirable from a conservation point of view.

At present the policy in most Atlantic snow crab fishing areas is to close fisheries when the proportion of white crab in catches exceeds 20 %. Whether protection of soft-shelled or white crab is a conservation measure, as opposed to an economic measure, has been questioned. Soft-shelled crabs are considered as bad quality animals by the industry (less and bad quality meat and soft shell). Soft shell crabs that are returned to the sea or are not caught have an opportunity to contribute to the reproductive pool as well as to become available for capture later when the shell has hardened and meat yield and quality have increased considerably. Fishermen generally support protection of soft-shelled crabs. Avoiding capture of soft-shelled crab by adjusting seasons or using closure protocols is an effective conservation measure, as is discarding of soft crab. However, careful handling of the soft-shelled animals discarded is essential. Crabs should be handled such that loss of limbs, carapace damage and exposure to wind, heat and extreme cold is minimized, and should be returned to the water as quickly as possible. This is particularly important during the summer months when desiccation and heat stress are a potential factor in mortality. Discarding mortality can be low when soft-shelled are discarded properly. Discarding mortality varies depending on condition and can be less than or equal to 32 % (Taylor *et al.* 1989) or around 14 % (Dufour *et al.* 1997).

6.2 Southern Gulf of St. Lawrence snow crab

New management measures were introduced in 1990: 1) A quota (global and per vessel) based on the biomass of adult hard shelled males ≥ 95 mm CW accumulated over a period of at least one year; and 2) Avoid the soft-shelled crab in catches because they are in poor commercial quality, unable to participate in mating, and represent recruits for the following fishing seasons.

DFO Sciences (Maritimes Area) has carried out an intensive sampling program since 1990 (observer program) on board commercial vessels to provide a weekly assessment of the percentage of soft-shelled crab in the catches. Between 1990 and 1997, the fishery was closed when the percentage of soft-shelled crab exceeded 20 % in number for two consecutive week. Monitoring soft-shelled crab in the catches during the fishery is achieved using a durometer gauge. For each trap sampled, the position, depth, and total number of male crab are recorded. A sub-sample of 40 males is chosen at random and the following measurements were taken: carapace width, chela height, carapace condition (categories into five groups) and the hardness of the base of the propodus of the right claw measured with a durometer. Individuals with a claw hardness less than 68 with a carapace conditions 1 and 2 are considered as soft-shelled crab. In 1997, a new protocol for daily monitoring of the soft-shelled crab was put in place for the southern Gulf of St. Lawrence fisheries. The purpose is to protect recruitment to the fishery and to decrease fishing effort in areas where the percentage of soft-shelled crab exceeds 20 %, without closing the whole fishery. A notice was given to the industry to leave, on a voluntary basis, the grids or areas where the percentage of soft-shelled crab exceed 20 % during the fishing season. In this protocol, the fisheries can be closed on a daily basis when the percentage of soft-shelled crab reaches 20 % in number for two consecutive periods of a five day analysis. A 48-hours notice is given to fishers for the implementation of any closure. If fishers do not co-operate the department of Fisheries and Oceans can close the whole Area.

7 INFLUENCE OF NO HARVEST MARINE PROTECTED AREAS ON CONSERVATION OF THE REPRODUCTIVE POTENTIAL AND/OR ESSENTIAL HABITATS FOR A SPECIES

Most significant crustacean resources world-wide are now fully exploited over the entire range of the species, and some have been intensely exploited for decades. Orensanz and Jamieson (1998) discussed why benthic shellfish resources in particular seem able to persist under fishing pressures which would likely collapse most finfish populations, and concluded that this was likely in part due to the apparent present of refuge areas where the exploited species could still maintain a high reproductive capacity. However, as fishing technology improves and world demand for high-value products increases, such refuges are becoming ever more rare. To ensure that population reproductive potential can be maintained, there is increasing recognition that additional management measures, and in particular the establishment of "strict preservation, or no-take areas", are needed. In addition, for Dungeness crab (*Cancer* magister) in the north-east Pacific Jamieson *et al.* (1998) discussed possible selective implications, and this subject was again covered at a Session at the 4Th International Crustacean Conference in Amsterdam in July, 1998. There is difficulty in disentangling genetic from phenotypic based changes in a fished population, and this difficulty is probably responsible for the general lack of attention paid to this issue to date by both fisheries researchers and managers, despite the topic being repeatedly brought up in the literature. Confusion arises from compensatory affects, Baranov's 'fishing-up' effect; in longer lived species, old fish are subject to repeated fishing for a longer time than younger ones, causing the average growth rate of remaining fish to be higher than for the population as a whole, since growth rates of younger fish are higher than for older fish), possible migrations into or out of study areas, and environmental changes, such as natural cycles or even global warming, not directly related to fishing.

Further confusion arises from changing fishing practices over time, due to technological developments and changing market demand, and changes in the quality and quantity of research data available for time series analyses. Data collected for a particular reason may not be particularly appropriate to investigate a different factor such as possible genetic change in a species' characteristics over time.

Nevertheless, while reasons to either defer study or to fail in adopting appropriate management actions might be understandable, they are not justifiable. Arguments that selective fishing can cause evolution go back to at least 1957, and with the declared goal of most fisheries management authorities to lean towards the side of conservation, fisheries should be managed, even in the absence of clear scientific advice, to minimize the likelihood of their causing species' selection. Clear evidence of the effects of fishing selection may best be evaluated through experimental fisheries management and/or simulation of species population dynamics, but we suggest that fisheries managers not even wait for these evaluations before adopting preventive measures, since there is considerable evidence in the literature that heritable variation exists, and that fishing can cause differential reproduction of genotypes. Ignorance of understanding does not affect the progress of a species' evolution, and its possible effects, both biological and economic, not be minimized or overlooked. What then can managers of crustacean fisheries do immediately to minimize potential negative evolutionary consequences of fishing practices, which can potentially have serious economic consequences to the fishers involved.

Phenotypic or genotypic selection may already be happening due to the following causes:

a) significant fishery removal, including poaching, below the age/size of sexual maturity;

b) fishing mortality is sufficiently high that few animals survive beyond any age of recruitment which is low enough for many, if not most, fished animals not to have mated before removal. Consequently, a specific cohort (e.g., the smallest mature males) in the population subsequently does most of the mating;

c) increased mortality of cohorts (which might be independent of size) which have, for example, specific behavioral or morphological traits making them vulnerable to the fishing gear or indirect fishing mortality, thus decreasing their lifetime reproductive contribution. Examples are i) the capture of large females in male-only crab fisheries (small females can escape through the escape ports), and their subsequent increased mortality through rough handling in the discard process, and ii) incidental capture of bycatch shrimp species in shrimp trawling, which might favour selection for other habitat preferences. Increased mortality may thus arise from exploitation of another species entirely so that the impacted crustacean species does not have to be the fishery targeted species;

d) distinct stocks with limited larval dispersal. Although not currently exploited (there was a limited fishery in the 1970–80's,), a relict population of golden king crab, *Lithodes aequispina*, occurs in an isolated silled, deep British Columbian fjord, geographically distant from open ocean populations now found odd the Aleutian Peninsula. There is no source of larval recruitment for this isolated population other than its own larvae production;

e) significant disruption of habitat by fishing. Habitat disturbance is likely to be associated with population effects only when habitats are significantly disrupted, such as by hydraulic dredging gear or bottom drags or trawls. Relatively small, isolated populations are again potentially most vulnerable;

f) significant trophic food chain disruption in a manner which affects the crustacean species being considered. I know of no examples where trophic chain disruption has negatively affected a crustacean, but a release from possible selective pressure may be currently happening because of the collapse of northern cod (*Gadus morhua*) populations from overfishing off Newfoundland. Cod was a significant crab predator, and a significant increase in *Chionoecetes opilio* abundance is presently occurring, with subsequent crab fishery expansion (D. Taylor, Dept. Fisheries and Oceans, Newfoundland, pers. comm.).

Preventative management actions to maximize population fecundity and to minimize opportunity for selective modification of a species' life history characteristics, whether the result of genetic change or phenotypic plasticity, which should exist, or be implemented, in every crustacean fishery include the following:

1) fishing practices should ensure that every exploited individual has had appropriate opportunity to reproduce before it is subject to capture. This may mean increasing the size of the minimum legal size limit, or if the recruiting sizeclass is the first sexually mature instar, delaying onset of the fishery until after the mating and/or egg hatching period(s). This will at least ensure that every genotype in the population reproduces.

2) much of the selective effects of fishing might be ameliorated if managers ensure that the entire population of the exploited species is not subject to fishing. Marine protected areas are increasingly becoming recognized in temperate waters as a potentially important management tool, both to enhance recruitment and to conserve genetic diversity (Orensanz and Jamieson 1998). Many existing, so-called protected areas effectively protect little, as they are often established by a level of government which has no mandate to control fishing (e.g., municipal or provincial parks, when control of fishing is a federal mandate), but if strict preservation, or no-take, refugia are established at a scale and spatial distribution which is meaningful for effective population conservation, then this approach can go a long way to mitigating the effect of an otherwise less-than-perfect fishing management process.

3) to ensure the continuance of effective management measures, whether they be a modified fishing process or establishment of protected areas, the public and fishers need to be educated as to the need for this conservation, and their buy-in into the process maintained. Education is an ongoing process, as not only in there turnover in human populations.

8 CONCLUSIONS

Based on the available data about the biology and fishery for the spider crab in Galicia (NW Spain) the management of the fishery should consider: 1) increasing the minimum landing size (at least to approx. 130 mm CL); 2) modifying the closed season (to reduce the fishing effort allowing a greater reproductive stock and an increase in the economical return [price per kg]); 3) establish protected areas in shallow water (juvenile habitat) and/or deep water (migratory and mating habitats for adults).

The available data about the biology and fishery of the velvet swimming crab in Spain is insufficient to allow an analysis of the current management regulations (especially for the trap fishery on rocky bottoms), however some aspects should be considered: 1) in raft areas the size at sexual maturity (CL aprox. 41 mm) is slightly lower than the minimum landing size, but no data are available from rocky areas; 2) the closed season should be modified to protect soft crabs (decreasing the indirect mortality imposed by the fishery); a closed season from approximately May to November should be considered.

For *Cancer pagurus* the main assessment method is to derive yield per recruit estimates from the length cohort method. New assessments using this method are currently in progress in England and Wales, but the lack of substantive data on growth and natural morality and on the spatial and temporal variability in the size structure data raises problems about the application of this method. The absence of data on stock and recruitment is also a problem. In Ireland the exploitation of undersized and soft-shelled crab for whelk bait fishery suggests that yield per recruit is not being optimised. Y/R assessments should therefore be carried out in fisheries where landing of soft-shelled, undersized crab and crab claws occurs in order to demonstrate the negative impact on yields due to this practice. Because of the current poor understanding of spatial and temporal changes in size structure data and the poor quality of growth parameters, assessments other than Y/R should be initiated. In particular the use of depletion methods for fisheries where precise fishing location (geographic) data is available should be attempted. This would also enable a sensitivity analysis for the effects of different spatial resolution in the catch effort data to be evaluated. The behaviour of the offshore fleet in Ireland suggests that depletion methods could be useful to evaluate exploitation rates as distinct patches are fished for periods of time until CPUE drops. In the report for the French *Cancer* fisheries the expected improvement in the inshore catch effort statistics is mentioned. These data should therefore be used more intensively in European fisheries in the Future.

Offshore fisheries for *Cancer* have developed in Ireland, Britain and France in recent years. In Ireland and Britain the sex ratio of the catch in this fishery is over 80 % mature female. As the location and behaviour of breeding females is unknown the possible effects of these new fisheries on recruitment to inshore traditional fisheries should be evaluated. This could be achieved through mapping of larval distributions to locate spawning (distribution of Zoea 1) and possible settlement (distribution of megalopae) areas. A time series of settlement / recruitment indices should be initiated using diver operated suction sampling methods in a number of locations. This could detect if egg production was limiting recruitment in areas with and without offshore fisheries.

Huge research effort were made on the Canadian snow crab in the last decade. These new insights increased the knowledge on that species and contributed to valuable changes in the management of these stocks. However, since the beginning of the exploitation is relatively recent (started at the end of the sixties) effects will have to be studied on a longer period of time before an exhaustive understanding of their consequences and specific adjustments would be made to insure a long term conservation of these stocks. Basic researches on the biology and ecology of snow crab are encouraged and researches on the influence of the environmental factors and crab habitat, on a more "systematic" fashion, should be also implemented in the future.

This third meeting of the SGCRAB group promoted a successful exchange of new knowledge and considerable discussion about the relation between assessment methodology and biological understanding. Previous study group members from Europe and Canada were joined by scientists from Ireland and England, contributing to the quality of the exchanges and increasing the cumulative knowledge of the group on exploited crab species. The presentations provided some indication that some crab stocks are subject to a high level of exploitation, and that assessment methods need to be reviewed and updated accordingly. **The Study Group recommends that it should pursue the questions of stock structure, assessment methods, stock and recruitment, biological reference points, and the effect of environmental variation on abundance, by correspondence, in order to prepare for a meeting to assess stocks of edible crab, spider crab, velvet crab, and snow crab, in the year 2001. The participation of crab experts from other part of the world (USA, Russia, etc.) should be encouraged to increase the geographical coverage of the Study Group.**

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