

1
2
3 **TOWARDS SUSTAINABLE AND EFFICIENT USE OF FISHERY**
4 **RESOURCES; PRESENT AND FUTURE TRENDS.**
5
6

7 Blanco M.*, Sotelo C.G, Chapela M.J. and Pérez-Martín R.I.
8

9 Instituto de Investigaciones Marinas (CSIC)
10 Eduardo Cabello 6, 36208 VIGO (SPAIN)
11

12
13 * To whom correspondence should be addressed. e-mail: mblanco@iim.csic.es
14 Tel: 0034-986 231 930 (311)
15 Fax: 0034-986 292 762
16

17 **ABSTRACT.**

18 Present production of wild fish resources is around 85 millions tonnes per
19 year, and the maximum long-term potential of marine capture fisheries of some
20 areas and fisheries has been reached. However, not all that is obtained from
21 the sea is adequately used and three clearly differentiated factors can be taken
22 into account to explain this fact: discards, wastes on board and byproducts and
23 wastes ashore. Although some efforts has been employed for changing this
24 situation a more efficient and intelligent use of the natural resources extracted
25 from sea and wasted is needed.

26 In this article the present utilization of discards and fishery wastes and
27 the future trends and the expected future of fishery industry are presented.

28
29
30 **INTRODUCTION**
31

32 Fishing is an ancient activity and has played an important role to many
33 human societies since the dawn of civilization. As human societies became
34 more organized and acquired technological knowledge their fishing activity
35 changed accordingly. However, it was during the 19th century, and especially

1 during the 20th century, when fishing activity exhibited an expectacular and
2 dramatical change driven by several facts: the invention of freezing technology,
3 the increase in fishing effort by the introduction of steam trawling and all the
4 improvements in fishing gears. Some concern about the decrease of some fish
5 stocks of coastal waters emerged as early as 1885 (Kreuzer, 1974), when in
6 McIntosh's book "*Resources of the sea*" the established idea of the
7 inexhaustibility of the sea was regarded as erroneous, prompting the need to
8 conserve fish stocks.

9 The state of capture fisheries has been monitored since the creation in the
10 early 1960's of FAO Fishery Resources Division. As a result of these studies, it
11 was observed that the total world marine capture fish production was increasing
12 at a rate of 6% per year since 1950 (19.3 million tonnes) up to 1970 (around 60
13 million tonnes). The estimations for maximum potential for traditionally exploited
14 marine species, excluding cephalopods, was of 80-100 million tonnes per year,
15 time and further studies have supported these estimations. This amount was
16 overpassed in 1989 with more than 100 million of tonnes and 2002 with 134
17 million of tonnes. The contribution of marine captures to this production was
18 very high, around 86%, although during the last decades this contribution has
19 diminished thanks to the faster expansion of marine and inland water
20 aquaculture (FAO, 2005).

21 The present production of wild fish resources of the oceans is 85 millions
22 tonnes, almost the 63% of the total world fish production, giving to the
23 aquaculture an important role in this total production (around 30%) (FAO, 2005).
24 This situation is explained by the changes suffered in highly productive areas
25 and some stocks, where fishing captures suffered stagnation, suggesting that

1 the maximum long-term potential of marine capture fisheries has been reached
2 with these areas and stocks being overfished or some stocks not producing
3 their full expected potential (FAO, 2005).

4 However, not all that is obtained from the sea is adequately used and we
5 can mention three clearly differentiated aspects: discards, wastes on board and
6 byproducts and wastes at land.

7 *Discards*

8 The non intended capture of non-target fish species is a well-known feature
9 of fisheries. This is usually called by-catch and some organisms are retained for
10 sale while others are thrown back to the sea because of either low value or
11 legal requirements (Harrington, Myers & Rosenberg, 2005). It is widely
12 accepted that ecological impacts of by-catch are significant (Kelleher, 2005).

13 In particular, discarded by-catch is a serious conservation problem because
14 valuable living resources are wasted, populations of endangered species are
15 threatened, stocks already heavily exploited are further impacted and
16 ecosystem changes in the overall structure of trophic webs and habitats may
17 result (Morgan & Chuenpagdee, 2003).

18 Discards estimation is a very difficult task, some studies were regarded
19 as inaccurate mainly because they were based in data from the 1980s and early
20 1990s (17.9-39.5 million tonnes/year). More recent estimations based on
21 focused discard studies give lower values (7.3. million tonnes/year) (Kelleher,
22 2005).

23 Discards also promote a significant waste of potential food resources. Since
24 global marine fisheries catches are declining (Watson & Pauly, 2001) and
25 competition for depleted stocks is increasing, the ecological, social and

1 economic arguments to decrease by-catch have received greater attention from
2 policy makers, industry and the general public (FAO, 2005).

3 In this sense, some measures have been taken for the reduction of by-
4 catch, such as the use of more selective fishing gears, the introduction of
5 bycatch and discard regulations, the improvement in the enforcement of
6 regulatory measures, the reduction of effort in some major trawl fisheries and
7 the increased retention of bycatch for direct utilization (market opportunities,
8 fishmeal, silage etc.), etc. However, it is foreseen that the existence of by-catch
9 will continue and, since the future trend for international regulations is directed
10 towards the zero discards, means to convert discards into landed products will
11 be necessary, developing new markets and processing techniques for this type
12 of material.

13 *Wastes on board*

14 In terms of fishing capacity, nowadays there is an important part of the
15 fishing fleet processing the captures on board, generating subproducts (heads,
16 guts, skins, etc.) which are sent back to the sea. Besides partially wasting a
17 natural resource, these practices can generate some impacts such as
18 ecological problems (changes in the ecosystem structure), environmental
19 problems (keeping at sea toxic compounds derived from land: PCBs, dioxines,
20 heavy metals, etc.) and toxicological problems (spreading parasites present in
21 fish viscera, such as Anisakis).

22 *Subproducts and wastes at land*

23 Actual trends are, in one hand, a bigger elaboration and processing of
24 fishery products generating a bigger quantities of wastes at land, and in the

1 other, a bigger concentration of them due to implantation of new larger
2 industries rather than smaller ones, and less and better fish auctions.

3 Although much of these wastes are being already managed, either for the
4 fish meal and oil production or treated as urban solid waste, it is considered that
5 this kind of utilization/management is poorly efficient and that, with the present
6 technological development, a more smart and profitable use of them is possible.

7

8 **PRESENT UTILIZATION OF FISH RESOURCES**

9 Fish catches are used mainly for human consumption and other minor
10 uses include meal production, bait, and miscellaneous purposes. Fish for
11 human food represents around 78%, both in developed and developing
12 countries, leaving about 21% for non food uses (Vannuccini, 2004). Therefore,
13 fish and its derived byproducts are considered important from the nutritional
14 point of view, being world average fish consumption of 16 Kg/ person/ year, this
15 is especially true for some areas where the fish consumption per capita is
16 relatively high (James, 1984; Kent, 1987; Sikorski, Kolakowsky, & Pan, 1990).

17 Fish and parts of fish can have a variety of applications, figure 1 shows some of
18 the uses and potential uses of different parts of fish.

19 *Fish meal*

20 Fish meal is one of the main products obtained from fish waste, bycatch and
21 other abundant species, like anchovy (*Engraulis* sp.), menhaden (*Brevoortia*
22 sp.) and capelin (*Mallotus villosus*) (Hevrøøy, Sandnes & Hemre, 2004). Fish
23 meal is a relatively dry product composed mainly of protein (70%), minerals
24 (10%), fat (9%) and water (8%), it can have different qualities, in terms of
25 aminoacid profile, digestibility and palatability, depending on the raw material

1 used for its production and the type of process employed for obtaining the meal
2 (Gildber, 2002). Fish meal is mostly employed as ingredient in feed of fish and
3 crustaceans. Differences in fish meal quality can affect the growth and feed
4 efficiency ratios (Aksnes & Mundheim, 1997). Fresh raw material and stale raw
5 material can produce significant differences in the content of biogenic amines,
6 such as cadaverine, in the fish meal, reducing feed intake and feed efficiency.
7 Process conditions also affect the meal quality, protein digestibility is one of
8 the parameters used to test it, and in general high processing temperature
9 reduces protein digestibility. Therefore, although traditional fish meal was
10 focused in the production of an ingredient for feed from any kind of waste, the
11 trend now is to focus in a better use of marine bycatch and discards and
12 produce a better quality fish meal.

13 *Fish minces and restructured products*

14 Muscle is the most often used part of the fish since is the edible portion of it. But
15 fish can be dressed before, by hand or using mechanical filleters, and the
16 resulting fillet can constitute the main product, leaving some parts like
17 trimmings, etc. which can be used for different products like minced,
18 restructures, etc.

19 Restructured fishery products are products made from minced or
20 chopped muscle. Fish-restructured product have been developed using different
21 binding agents and techniques. The use of transglutaminase as a binding agent
22 is widely extended in food industry to induce covalent cross-linking of proteins,
23 joining pieces of fish muscle (Uresti, Tellez-Luis, Ramirez & Vazquez, 2004).

24 Surimi products are based upon techniques used traditionally in Japan,
25 and usually the resulting products could have a variety of forms and textures,

1 imitating the characteristics of natural products (Borderias & Perez-Mateos,
2 2005). Surimi is a paste formed by myofibrillar proteins which is obtained from
3 mechanical deboned fish flesh washed with salt solutions to remove
4 sarcoplasmic proteins and stabilized with the inclusion of cryoprotectants. It is
5 an intermediate product used in a variety of products such as the traditional
6 Japanese *kamaboko* or different preparations of shellfish substitutes (crab legs,
7 crab meat, young eel, etc.).

8 *Collagen and gelatines*

9 Skin, bones and fins are produced as a consequence of the preparation
10 of different fishery products such as fillets, sashimi (sliced raw fresh fish) etc.,
11 representing around 30% of the fish fillet processing waste. Fish skin therefore
12 is an important byproduct of the fish-processing industry, causing wastage and
13 pollution. Skins and bones are a rich source of gelatins and collagen, collagen
14 is the major structural protein found in skin and bones of animals, and gelatines
15 are collagen degradation products. Several studies were carried out to obtain
16 collagens from skins, bones, scales, fins of different fish species, and
17 invertebrates, that otherwise may be dumped as waste (Morimura, Nagata,
18 Uemura, Fahimi, Shigematsu & Kida, 2002, Senaratne, Park & Kim, 2006).
19 Nagai & Suzuki (2000) reported the obtention of high yield of collagen from fish
20 skin, bone and fins (about 36-54%). The collagen obtained has potential use for
21 a variety of applications: edible casings for the meat processing industries,
22 cosmetics as it has good moisturizing properties (Swatschek, Schatton,
23 Kellerman, Muller & Kreuter, 2002) and biomedical materials or pharmaceutical
24 applications which includes production of wound dressings, vitreous implants or
25 carriers for drug delivery (Takeshi & Suzuki, 2000). Furthermore, Morimura et

1 al. (2002) found that the hydrolysates derived from fish bone would be suitable
2 as a food additive due its high anti-radical activity.

3 The outbreak of mad cow disease and the necessity to meet religious
4 requirements (Jewish and Muslim markets), has resulted in an increased
5 attention for fish gelatine, however nowadays the fish gelatine production is still
6 minor, yielding about 1% of the annual world gelatine production of 250,000
7 tons (Arnesen & Gildberg, 2006). Nevertheless, the amount of gelatine used in
8 the food industry worldwide is increasing annually (Montero & Gomez-Guillen,
9 2000).

10 Extraction of gelatine has been reported for cod (Gudmundsson &
11 Hafsteinsson, 1997), tilapia (Grossman & Bergman 1992, Jamilah & Harvinder
12 2002), shark, lungfish and carp skin (Ward & Courts, 1977), snapper
13 (Jongjareonrak, Benjakul, Visessanguan, Prodpran, & Tanaka, 2006), Alaska
14 pollock (Zhou & Regenstein, 2005), Yellowfin tuna (Cho, Gu & Kim, 2005), Sin
15 croaker and Decapterus macrosoma (Cheow, Norizah, Kyaw & Howell, 2006),
16 Cod head (Arnesen & Gildberg, A. 2006).

17 Choi & Regenstein (2000) found that fish gelatin has similar properties to
18 pork gelatin, but its lower melting point, compared with pork or beef, together
19 with the fact that fish gelatin has a better release of aroma and gives a stronger
20 flavor, could offer new opportunities to product developers. Gómez-Guillén,
21 Turnay, Fernandez-Diaz, Ulmo, Lizarbe & Montero (2002) made a comparative
22 study of the structural and physical properties of gelatin extracted from different
23 marine species, they concluded that the best gelatin preparations regarding the
24 viscoelastic properties and gel strength were those obtained from sole (*Solea*
25 *vulgaris*) and megrim (*Lepidorhombus boscii*).

1 Furthermore, the study of Surh, Decker & McClements (2006) provides
2 information about the potential applications of fish gelatins as emulsifiers in food
3 products, demonstrating that fish gelatin stabilized emulsions, remained
4 moderately stable to droplet aggregation and creaming, after being subjected to
5 changes in temperature, salt concentration and pH.

6 Jongjareonraka et al. (2006) studied and characterized the skin gelatin
7 from two snapper species, finding that strong and transparent edible films could
8 be prepared successfully with these gelatins.

9 *Fish silage and Fish protein hydrolysates*

10 Viscera of fish include the digestive tissues (stomachs, pyloric caeca, intestines,
11 liver, pancreas, etc.) and some other organs like spleen and gonads.

12 Viscera wastes were used to obtain fish protein hydrolysates (FPH) and fish
13 silages. FPH and silages constitute a broadly accepted nitrogen source for rats,
14 pets, aquaculture, bacteria and other commercially grown organisms (Clausen,
15 Gilberg & Raa 1985; Fagbenro & Jauncey 1998; Coello, Montiel & Concepcion,
16 2002, Martone, Borla & Sanchez 2005), reducing the cost of nitrogen supply in
17 feeds and culture media (Dufosse, De la Broise & Guerard 2001). Vazquez,
18 Gonzalez & Murado (2004) found that hydrolysates from fish viscera wastes
19 can substitute other peptones for culture of lactic acid bacteria, permitting the
20 production of biomass and bacteriocins, with equal or superior qualities than
21 those obtained with common commercial media. Vidotti, Viegas & Carneiro
22 (2003) evaluated the amino acid composition of silages produced from fish as
23 supplement in fish feeds, as the nutritional value of aquaculture fish diet is
24 determined basically by its amino acid composition. Authors concluded that

1 silages made from fish wastes materials are adequate to be used as an
2 ingredient in balanced diets.

3 *Enzymes*

4 Digestive organs of viscera were investigated to see the possibilities
5 offered by enzymes, mostly proteases, present in them. Applications include
6 biotechnology, clinical applications, diagnosis and physiological processes
7 (Batista & Pires, 2002). The digestive proteolytic enzymes studied include
8 pepsin, trypsin, chymotrypsin, gastricins and elastase. Marine digestive
9 proteases are especially interesting for the food industry due its unique
10 properties, which include high catalytic efficiency at low reaction temperatures,
11 lower thermostability, and cold stability (Simpson, 2000). The specific
12 characteristics which make marine proteases different from terrestrial have
13 emerged by the adaptation of marine animals to special environment conditions,
14 particularly to cold temperatures. In some cases, and it seems to be the trend in
15 the future, enzymes and other recovered products, are obtained from waste
16 material from the fishing industry (Almas 1990, Raa 1990, Haard 1992)

17 *Fish oils*

18 Fish oils can be extracted from the whole fish, skins or livers (in the case
19 of some species). Fish oils are rich sources of polyunsaturated fatty acids,
20 especially eicosapentaenoic acid (EPS) and docosahexanoic acid (DHA), these
21 two compounds have shown different interesting bioactivities. Among the
22 properties of omega-3 fatty acids the best known are: prevention of
23 atherosclerosis (Schacky, 2000), reduction of blood pressure (Appel, Miller,
24 Seidler & Whelton, 1993), protection against arrhythmias (Christensen, Korup,
25 Aaroe, Toft, Moller & Rasmusen, 1997).

1 Squalene is a lipid found in large quantities in shark liver oil. The large
2 bycatch of shark in fishing industry around the world provides a useful source
3 for fish oils whose value, can be substantially increased by processing it to
4 obtain fractions such as the squalene. Bakes & Nichols (1995) analyzed the
5 liver oils from several deep-sea sharks to describe their composition. For almost
6 all species studied, it was found a high squalene content (50-80% of oil),
7 suggesting that oil from sharks will be suitable for industrial uses. In a more
8 recent study, Catchpole, Grey & Noermark (2000), reports the fractionation of
9 fish oils using supercritical extraction with CO₂ and CO₂ with ethanol mixtures,
10 recovering specific fractions such as squalene. Squalene is an interesting bio-
11 active oil and it has been reported its application in diabetes treatments, cancer
12 and tuberculosis, it also has antifungal and antioxidative properties (Archer,
13 Watson & Denton, 2001).

14

15 **FUTURE TRENDS IN THE TOTAL UTILIZATION OF FISH**

16 It is clear that the situation of utilization of wastes and discards have
17 changed dramatically from that of the 1950's: now there are more possibilities
18 for enhancing returns by extraction and utilization of fishery byproducts
19 (Gildberg, 2002), but still there are more to come. In this section we will mention
20 some of these new compounds which can be obtained from fish and that can
21 constitute an incipient industry or the possibility to become so.

22 *Bio-active compounds*

23 New biological active compounds have been isolated from fishery
24 discards, one example is the discover of the antifungal and antibacterial
25 properties of the epidermis, epidermal mucus of different fish species, liver,

1 intestine, stomach, and gills of some fish species (Richards, O'Neill, Thibault &
2 Ewart, 2001; Lijima, 2003) and the blood and shell of some crustaceans.

3 Fish mucus is known to have important biological functions acting as an
4 immunological barrier (Fletcher & Grant 1969, Austin & MacIntoch 1988; Fouz,
5 Devesa, Gravningen, Barja & Tranzo, 1990; Ingram 1980). A variety of
6 biologically active compounds are responsible for these functions: proteinases,
7 peptides, or polypeptides with high molecular weight, as well as the presence of
8 immunoglobulin, lysozyme or precipitin in the epidermal mucus were reported
9 as fundamental in the avoidance of colonization by bacteria, fungi and other
10 aquatic parasites (Ourth 1980, Smith, Fernandes, Jones, Kemp & Tatner, 2000;
11 Braun, Arnesen, Rinne & Hjelmeland, 1990; Takahashi, Itami & Kajiwaki 1992,
12 Park, Park, Kim & Kim,1998; Nagashima, Kikuchi, Shimakura & Shiomi, 2003).

13 In another recent study, Patat, Carnegie, Kingsbury, Gross, Chapman &
14 Schey (2004) reported relevant data indicating that shrimp hemocyte histone
15 proteins present antimicrobial activity, representing a defense mechanism for
16 these organisms.

17 Chitin is a polysaccharide, one of the major components from crustacean
18 shell wastes, and has been found to be a potential source of antimicrobial
19 substances, due the high percentage that shrimp wastes represent at a global
20 scale. Chitosan has strong antimicrobial activity against a variety of
21 microorganisms, and its properties, non-toxic, biocompatible and
22 biodegradable, make it adequate for its applications as a food ingredient and in
23 medical applications, (Tsai & Hwang 2004; Sudarshan, Hooever & Knorr, 1992;
24 Chen, Liao & Tsai, 1998; Fang, Li & Shin, 1994). Suzuki, Owaga, Okura,
25 Hashimoto & Suzuki (1982, 1984) found that chitosan could be used for

1 protection of animals against *Candida albicans* and *Staphylococcus aureus*
2 infections. Also, it was found that chitosan could activate macrophages and
3 cytotoxic T lymphocytes and therefore protecting mice against bacteria
4 infections (Nishimura, Nishimura, Nishi, Saiki, Tokura & Azuma, 1984; Tsai &
5 Su, 1999). It has also some antitumor properties revealed both in vitro and in
6 vivo (Jeom & Kim, 2002). Besides the antimicrobial effect, chitosan has also
7 been identified as effective in reducing LDL-cholesterol levels in liver and blood
8 (Kanauchi, Deuchi, Imasato, Shizukuishi & Kobayashi, 1995), the mechanism
9 suggested is that these compounds act as fat scavengers, removing fat and
10 cholesterol in the digestive tract and promoting their excretion (Ikeda, Suganoi,
11 Yoshida, Sasaki, Iwamoto & Hatano, 1993).

12 Chitooligosaccharides also exhibited scavenging activity on hydroxyl and
13 superoxide radicals, these being dependent on their molecular weight (Park, Je
14 & Kim, 2003), this property make them potential additives for the inhibition of
15 lipid oxidation in food, but also to prevent some pathological processes
16 associated with free radical modification of cellular compounds, such as
17 atherosclerosis, arthritis, diabetes, inflammatory disorders, and neurological
18 disorders such as Alzheimer's disease (Frlich & Riederer, 1995).

19 Other applications of chitin and chitosans are their use as an ingredient
20 of toothpaste, shampoo, hand and body cream, for cell immobilization, and
21 material for production of contact lens (Sugano, Watanabe, Kishi, Izume &
22 Ohtakara, 1988; Shahidi & Synowiecki, 1991).

23 *Pigments*

24 Valuable pigments have been found in a variety of fish raw materials,
25 especially in seafood wastes. Various studies have reported the presence and

1 recovering of pigments such astaxanthin and its esters, β -carotene, lutein,
2 astacene, canthaxanthin and zeaxanthin in crustacean waste.

3 Carotenoids are a group of fat-soluble pigments that can be found in
4 many plants, algae, micro-organism and animals, and are responsible for the
5 colour of several shellfish. Carotenoids have been extracted using shrimp
6 waste, from processing head and shell of *Penaeus indicus*, applying different
7 organic solvents (Sachindra, Bhaskar & Mahendrakar, 2005). Carotenoids were
8 also extracted from fish eggs as reported Li, Tyndale, Heath & Letcher (2005),
9 and from fish scales waste (Stepnowski, Olafsson, Helgason & Jasturff, 2004).
10 These valuable pigments would be a cheaper alternative applicable to a wide
11 variety of industrial needs such as coloration of some surimi based products or
12 aquaculture feed formulation.

13 Furthermore, some pigments like asthaxanthin are important in medical
14 and biomedical applications due its high antioxidative effects and to the fact of
15 being a precursor of vitamin A.

16 *Antifreeze proteins*

17 Antifreeze proteins (AFPs), which are found in diverse species of marine
18 fishes, are characterised by their ability to prevent ice from growing upon
19 cooling below the freezing point. This is a protecting method of polar fishes
20 against freezing. Evans & Fletcher (2004), found that snailfish skin tissue
21 contains antifreeze activity that can be purified by chromatography techniques.
22 Some work has also been carried out on the extraction of AFPs from winter
23 flounder (*Pseudopleuronectes americanus*), cunner (*Tautoglabrus adspersus*),
24 sea raven (*Hemitripterus americanus*), and shorthorn sculpin (*Myoxocephalus*
25 *scorpius*). AFPs have a main application as cryoprotectants since they can

1 prevent freezing damage by their lowering freezing point capacity and the
2 inhibition of ice recrystallisation. Some studies revealed that the addition to meat
3 or injection to animals of AFP reduce the damage due to frozen storage of their
4 meat (Payne & Young, 1995).

5 *Lectins*

6 Lectins are sugar-binding proteins that agglutinate cells and/or precipitate
7 glycoconjugates by establishing stable complexes. Lectins are widely found in
8 reproductive cells, eggs and sperms, because of its role in fertilization. The
9 ability of lectins to bind with carbohydrates makes them a suitable alternative for
10 antibiotics, since they can bind the carbohydrate layer in bacterial walls making
11 pathogens unable to cause disease (Kim & Mendis, 2006).

12 *Fish leather*

13 Another use for the fish skin is to process it in leather. The aquatic source of
14 skin would be desirable in areas where green pastures are scarce leading a
15 lack of cattle. Fishes can be converted into leather by similar methods than
16 those already applicable to skins from land animals (Flick & Martin, 2000).

17

18 **CONCLUDING REMARKS**

19 The main problems to face when trying to implement and enforce
20 management measures in fishery activities, are those related with the
21 infrastructure needed both on board vessels and ashore. Regarding the high
22 perishability of most fish species, immediate processing is needed. This leads
23 to the necessity to establish and implement protocols of by-product separation,
24 classification and storage, as well as proposals for conservation or pre-

1 processing alternatives when possible, either on board or in land, so to maintain
2 the materials in the appropriate processing conditions.

3 Some of the main obstacles to implement the technology for obtaining
4 benefits from discards and by-catch are the following:

5 - Scarce investment in new technologies applied to discards and by-
6 catch to obtain higher added-value products.

7 - Limited storage facilities of trawlers and preference to maximize
8 storage of species with high commercial value, than those discards or
9 by-catch which currently have lower price in markets.

10 - Lack of a global policy framework and severe legislation regarding
11 discards and by-catch.

12 The states should enhance good-fishery-practices, and promote standards
13 of conduct in every sector involved in fishery practices, leading the progress of
14 awareness of environmental protection, encouraging the crew to be involved in
15 educational programmes focused on responsible fishing and sustainable
16 development practices.

17 The implementation of the practices, procedures and machinery to fishing
18 fleets, fish auctions and related industries will induce a substantial degree of
19 innovation inside the related sectors, improving the sustainability of marine
20 resources, the rational exploitation of fisheries, the reduction of pollution, and
21 new employment opportunities and economic activities.

22

23 REFERENCES

24 Aksnes A., Mundheim H. (1997). The impact of raw material freshness and
25 processing temperature for fish meal on growth, feed efficiency and chemical

- 1 composition of Atlantic halibut (*Hippoglossus hippoglossus*). *Aquaculture* 149:
2 87-106.
- 3 Almas (1990). Utilization of marine biomass for production of microbial growth
4 media and biochemicals. In *Advances in fisheries technology and biotechnology*
5 *for increased profitability*. (M.N. Voigt and J.R. Botta, eds.). pp.361-372.
- 6 Appel L.J., Miller E.R., Seidler A.J., Whelton P.K. (1993). Does supplementation
7 of diet with "fish oil" reduce blood pressure? A metanalysis of controlled clinical
8 trials. *Archives of Internal Medicine*, 153: 1429-1438
- 9 Archer, M., Watson, R. & Denton, J.W. (2001). Fish waste production in the
10 United Kingdom- The quantities produced and opportunities for better utilisation.
11 *Seafish Report N° SR537*.
- 12 Arnesen, J.A., & Gildberg, A. (2006). Extraction of muscle proteins and gelatine
13 from cod head. *Process Biochemistry*, 41, 697-700.
- 14 Austin, B., & McIntosh, D., (1988). Natural Antibacterial Compounds on the
15 Surface of Rainbow-Trout, *Salmo-Gairdneri* Richardson. *Journal of Fish*
16 *Diseases* 11, 275-277.
- 17 Bakes, M.J. & Nichols, P.D. (1995). Lipid, fatty acid and squalene composition of
18 liver oil from six species of deep-sea sharks collected in southern Australian
19 waters. *Comparative Biochemistry and Physiology*, 110B (1), 267-275.
- 20 Batista, I., & Pires, C. (2002). Comparative studies of the proteolytic activity of
21 crude extracts from the digestive tract of three shark species. *Journal of aquatic*
22 *food product technology*, 11, 151-165.
- 23 Borderías, A.J. & Pérez-Mateos, M. (2005). Sucedáneos de productos
24 pesqueros: tecnología de reestructuración. *Alimentación, Nutrición y Salud*,
25 12(2), 61-70.
- 26 Braun, R., Arnesen, J.A., Rinne, A., Hjelmeland, K. (1990). Immunohistological
27 localization of trypsin in mucus-secreting cells layers of Atlantic salmon, *Salmo*
28 *salar* L. *Journal of fish disease*, 13, 233-238.
- 29 Catchpole, O.J., Grey, J.B. & Noermark, K.A. (2000). Fractionation of fish oils
30 using supercritical CO₂, and CO₂+ ethanol mixtures. *Journal of supercritical*
31 *fluids*, 19, 25-37.
- 32 Chen, C. S., Liao, W.Y. & Tsai, G.J. (1998). Antibacterial Effects of N-
33 sulfobenzoyl Chitosan and application to Oyster Preservation. *Journal of Food*
34 *Protection*, 61, 1124-1128.
- 35 Cheow, C.S., Norizah, M.S., Kyaw, Z.Y., Howell, N.K. (2006). Preparation and
36 characterisation of gelatins from the skins of sin croaker (*Johnius dussumieri*)
37 and shortfin scad (*Decapterus macrosoma*). *Food chemistry*. In press.

- 1 Cho, S.M., Gu. Y.S., Kim, S.B. (2005) Extracting optimization and physical
2 properties of yellowfin tuna (*Thunnus albacares*) skin gelatine compared to
3 mammalian gelatins. *Food hydrocolloids*, 19, 221-229.
- 4 Choi, S.-S. & Regenstein, J.M. (2000). Physicochemical and sensory
5 characteristics of fish gelatin. *Journal of food science*, 65, 2.
- 6 Christensen J.H., Korup E., Aaroe J., Toft E., Moller J., Rasmussen K. (1997).
7 Fish consumption n-3 fatty acids in cell membranes, and heart rate variability in
8 survivors of myocardial infraction with left ventricular disfunction. *American*
9 *Journal of Cardiology*,79, 1670-1673.
- 10 Clausen, E., Gildberg, A., Raa, J. (1985). Preparation and testing of an
11 autolysate of fish viscera as growth substrate for bacteria. *Applied and*
12 *Environmental Microbiology*, 50, 1556-1557.
- 13 Coello, N., Montiel, E. & Concepcion, M. (2002). Optimisation of a culture
14 medium containing fish silage for L-lysine production by *Corynebacterium*
15 *glutamicum*. *Biosource Technology*, 85, 207-211.
- 16 Dufossé, D., De la broise, D., Guérard, F. (2001). Evaluation of nitrogenous
17 substrates such as peptones from fish : a new method based on Gompertz
18 modeling of microbial growth. *Current microbiology*, 42, 32-38.
- 19 Evans, R.P. & Fletcher, G.L. (2004). Isolation and purification of antifreeze
20 proteins from skin tissues of snailfish, cunner and sea raven. *Biochimica et*
21 *Biophysica acta*, 1700, 209-217.
- 22 Fagbenro, O.A. & Jauncey, K. (1998) Physical and nutritional properties of
23 moist fermented fish silage pellets as a protein supplement for tilapia
24 (*Oreochromis niloticus*). *Animal Feed Science and Technology* 71(1-2),11-18.
- 25 Fang, S. W., Li, C.J., & Shin.D.Y.C. (1994). Antifungal Activity of Chitosan and
26 its preservative Effect on Low-sugar Candied Kumquat. *Journal of Food*
27 *Protection* 56, 136-140.
- 28 FAO. 2005. Review of the state of world marine fishery resources. *FAO*
29 *Fisheries Technical Paper* 457.
- 30 Fletcher, T. C., & Grant, P. T. (1969). Immunoglobulin in the serum and mucus
31 of the plaice (*Pleuronectes platessa*). *Biochemical Journal*, 115 (65).
- 32 Flick, G.J. & Martin, R.E.(2000). Industrial products: Leather production from
33 fish skins. In *Marine and freshwater products handbook*, (pp. 599-604).
- 34 Fouz, B., Devesa, S., Gravningen, K., Barja, J.L. and Tranzo, A.E. (1990).
35 Antibacterial action of the mucus of the turbot. *Bulletin of the European*
36 *Association for Fish Pathologists* 10, 56-59.

- 1 Frlich, I.; Riederer, P. (1995). Free radical mechanisms in dementia of
2 Alzheimer type and the potential for antioxidative treatment. *Drug Resistance*
3 *updates*, 45, 443-449.
4
- 5 Gildberg A. (2002). Enhancing returns from greater utilization. In *Safety and*
6 *quality issues in fish processing*. Bremner H.A. (Ed.), Woodhead Publishing
7 Ltd., Cambridge, England. (pp 425-449).
- 8 Gómez-Guillén, M.C., Turnay, J., Fernández-Díaz, M.D., Ulmo, N., Lizarbe,
9 M.A., Montero, P. (2002). *Food Hydrocolloids*, 16, 25-34.
- 10 Grossman, S., & Bergman, M.(1992). Process for the Production of Gelatin
11 from fish skins. U.S.Patent. 5, 093, 474.
- 12 Gudmundsson, M. & Hafsteinsson, H. (1997). Gelatin from cod skins as
13 affected by chemical treatments. *Journal of Food Science*, 62 (1), 37-39, 47.
- 14 Haard, N.F. (1992).A review of proteolytic enzymes from marine organisms and
15 their application in the food industry. *Journal of aquatic food product technology*.
16 1(1), 17-35.
- 17 Harrington, J.M., Myers, R.A., & Rosenberg A.A. (2005). Wasted fishery
18 resources: discarded bycatch in the USA. *Fish and Fisheries* 6, 350-361.
- 19 Hevrøy E.M., Sandnes K., Hemre G.-I. (2004). Growth, feed utilisation, appetite
20 and health in Atlantic salmon (*Salmo salar* L.) fed a new type of lipid fish meal,
21 Sea Grain®, processed from various pelagic marine fish species. *Aquaculture*
22 235, 371-392.
- 23 Ikeda, I., Sugano, M., Yoshida, K., Sasaki, E., Iwamoto, Y. & Hatano, K. (1993).
24 Effects of chitosan hydrolysate on lipid absorption and on serum and liver lipid
25 concentrations in rats. *Journal of Agricultural and Food Chemistry* 41, 431-435.
- 26 Ingram G. A. (1980) Substances involved in the natural resistance of fish to
27 infection - a review. *Journal of Fish Biology* 16, 23–60.
- 28 James, D. (1984). The future of fish nutrition. *Infofish marketing digest*, 4, 41-
29 44.
- 30 Jamilah, B. & Harvinder, K. G. (2002). Properties of gelatins from skins of fish -
31 black tilapia (*Oreochromis mossambicus*) and red tilapia (*Oreochromis*
32 *nilotica*). *Food Chemistry*, 77, 81-84.
- 33 Jeom Y.J., Kim S.K. 2002. Antitumor activity of chitosan oligosaccharides
34 produced in an ultrafiltration membrane reactor system. *Journal of Microbiology*
35 *and Biotechnology*, 12, 503-507.
- 36 Jongjareonrak, A., benjakul, S., Visessanguan, W., Prodpran, T., Tanaka, M.
37 (2006). Characterization of edible films from skin gelatine of brownstripe red
38 snapper and bigeye snapper. *Food hydrocolloids* 20, 492-501.

- 1 Kanauchi O., Deuchi K., Imasato Y., Shizukuishi M., Kobayashi E. (1995).
2 Mechanism for the inhibition of fat digestion by chitosan and for the synergistic
3 effect of ascorbate. *Bioscience Biotechnology and Biochemistry* 59: 786-790.
4
- 5 Kelleher K. (2005). Discards in the world's marine fisheries. An update. *FAO*
6 *Fisheries Technical Paper* N° 470. Rome, 131 pp.
- 7 Kent, G. (1987). Fish and nutrition in India. *Food policy*, 12 (5), 161-175.
- 8 Kims S.-K., Mendis E. (2006). Bioactive compounds from marine processing by-
9 products- a review. *Food Research International* 39, 383-393.
- 10 Kreuzer, R. (1974). Fish and its place in culture. In *Fishery products* (Ed. Kruzer
11 R.). Fishing News Books Ltd., West Byfleet, England.
- 12 Li, H., Tyndale, S.J., Heath, d.D., Letcher,R.J. (2005). Determination of
13 carotenoids and all-trans-retinol on fish eggs by liquid chromatography-
14 electrospray ionization-tandem mass spectrometry. *Journal of chromatography*,
15 816, 49-56.
- 16 Ljima, N. (2003). Purification and characterization of three isoforms of
17 chrysopsin, a novel antimicrobial peptide in the gills of the red sea bream,
18 *Chrysophrys major*. *European Journal of Biochemistry*, 270(4), 675-686.
- 19 Martone, C.B., Borla, O.P., Sánchez, J.J. (2005). Fishery by-product as a
20 nutrient source for bacteria and archaea growth media. *Bioresources*
21 *Technology* 96, 383-387.
- 22 Montero P, and Gómez-Guillén MC. 2000. Extracting Conditions for Megrim
23 (*Lepidorhombus boscii*) Skin Collagen Affect Functional Properties of the
24 Resulting Gelatin. *Journal of Food Science*, 65(3), 434-438.
- 25 Morgan, L., & Chuenpagdee, R. (2003). Shifting gears: addressing the collateral
26 impacts of fishing methods in USA waters. Island Press Publication Services,
27 Washington, DC.
- 28 Morimura, S., Nagata, H., Uemura, Y., Fahimi, A., Shigematsu, T., Kida, K.
29 (2002). *Process Biochemistry*, 37, 1403-1412.
- 30 Nagai, T., Suzuki, N. (2000). Isolation of collagen from fish waste material- skin,
31 bone and fins. *Food Chemistry*, 68, 277-281.
- 32 Nagashima, Y., Kikuchi, N., Shimakura, K., Shiomi, K. (2003). Purification and
33 characterization of an antibacterial protein in the skin secretion of rockfish
34 *Sebastes schlegeli*. *Comparative biochemistry and physiology part C*, 136, 63-
35 71.
- 36 Nishimura, K., Nishimura, S., Nishi, N., saiki, I., Tokura, S., Azuma, I. (1984).
37 Immunological activity of chitin and its derivatives. *Vaccine*, 2, 93-99.

- 1 Ourth, D.D. (1980). Secretory IgM, lysozyme and lymphocytes in the skin
2 mucus of the channel catfish, *Ictalurus punctatus*. *Developmental &*
3 *Comparative Immunology*, 4, 65-74.
- 4 Papineau, A.M., Hoover, D.G., Knorr, D. & Farkas, D.F.(1991). Antimicrobial
5 effect of water-soluble chitosans with high hydrostatic pressure. *Food*
6 *Biotechnology*, 5, 45–47.
- 7 Park I.Y., Park C.B., Kim M.S., Kim S.C. (1998) Parasin I, an antimicrobial
8 peptide derived from histone H2A in the catfish, *Parasilurus asotus*. *European*
9 *Journal of Biochemistry* 437, 258–262.
- 10 Park, P.J., Je, J.Y., & Kim, S.K. (2003). Free radical scavenging activity of
11 chitooligosaccharides by electron spin resonance spectrometry. *Journal of*
12 *Agricultural and Food Chemistry*, 51, 4624-4627.
- 13 Patat, S.A., Carnegie, R.B., Kingsbury, C., Gross, P.S., Chapman, R. & Schey,
14 K.L. (2004). Antimicrobial activity of histones from hemocytes of the Pacific
15 white shrimp. *European Journal of Biochemsitry*, 271, 4825-4833.
- 16 Payne S.R., & Young O.A. (1995). Effects of pre-slaughtther administration of
17 antifreeze proteins on frozen meat quality. *Meat Science*, 41 (2), 147-155.
- 18 Raa, J. (1990).Biotechnology in aquaculture and the fish processing industry; A
19 success story in Norway. In *Advances in fisheries technology and biotechnology*
20 *for increased profitability*. (M.N. Voigt and J.R. Botta, eds.). pp 509-534,
21 Technomic Publishing Co., Lancaster, PA.
- 22 Richards R.C., O'Neil D.B., Thibault P., Ewart K.V. (2001) Histone H1: an
23 antimicrobial protein of Atlantic salmon (*Salmo salar*). *Biochemistry and*
24 *Biophysics Research Communications*, 284,549–555.
- 25 Sachindra, N.M., Bhaskar, n., Mahendrakar, N.S. (2005). Carotenoids in
26 different body components of Indian shrimps. *Journal of the science of food and*
27 *agriculture*, 85, 167-172.
- 28 Schacky C.V. (2000). N-3 fatty acids and the prevention of coronary
29 atherosclerosis. *American Journal of Clinical Nutrition* 71, 224-227.
- 30 Senaratne, L.S., Park, P.J., kim, S.K. (2006). Isolation and characterization of a
31 collagen from brown backed toadfish (*Lagocephalus gloveri*) skin. *Bioresource*
32 *Technology*, 97, 191-197.
- 33 Shahidi, F. & Synowiecki, J. (1991). Isolation and characterisation of nutrients
34 and value added products from snow crab (*Chionoecetes opilio*) and shrimp
35 (*Pandalus borealis*) processing discards. *Journal of Agriculture and Food*
36 *Chemistry*, 39, 1527–1532.
- 37 Sikorski, Z.E., Kolakowski, A., Pan, B.S. (1990). The nutritive composition of the
38 major groups of marine food organisms. In *Sikorski Z.E. (cd), Seafood:*

- 1 *resources, nutritional composition and preservation*. CRC Press, Boca Raton,
2 Florida, (pp 29-54).
- 3 Simpson, B.K. (2000). Digestive proteinases from marine animals. In *Seafood*
4 *Enzymes. Utilization and Influence on Postharvest Seafood Quality*, (N.F. Haard
5 and B.K. Simpson, eds.). (pp. 191-213), Marcel Dekker, New York, NY.
- 6 Smith, V.J., Fernandes, J.M.O., Jones, S.J., Kemp, G.D., & Tatner, M.F. (2000).
7 Antibacterial proteins in rainbow trout, *Oncorhynchus mykiss*. *Fish and Shellfish*
8 *Immunology* 10, 243-260.
- 9 Stepnowski, P., Ólafsson, G., Helgason, H., & Jasturff, B. (2004) Recovery of
10 astaxanthin from seafood wastewater utilizing fish scales waste. *Chemosphere*,
11 54, 413-417.
- 12 Sudarshan NR, Hoover DG, Knorr D. (1992) Antibacterial action of chitosan.
13 *Food Biotechnology*, 6,257–272.
- 14 Sugano, M., Watanabe, S., Kishi, A., Izume, M. & Ohtakara, A. (1988)
15 Hypocholesterolemic action of chitosans with different viscosity in rats. *Lipids*,
16 23, 187-191.
- 17 Surh, J., Decker, E.A., McClements, D.J. (2006). Properties and stability of oil-
18 in-water emulsions stabilized by fish gelatine. *Food hydrocolloids*, 20,596-606.
- 19 Suzuki, S., Ogawa, Y., Okura, Y., Hashimoto, K., Suzuki, M.
20 (1982).Immunoadjuvant effect of chitin and chitosan. Hirano, S., Tokura, S.
21 (eds). In *Proceedings of the second international conference on chitin and*
22 *chitosan*, 12-14 July, Sapporo, Japan. The Japanese Society of Chitin and
23 Chitosan, tottori, Japan, (pp 210-212).
- 24 Suzuki, S., Ogawa, Y., Okura, Y., Hashimoto, K., Suzuki, M. (1984) Protecting
25 effect of chitin and chitosan on the experimentally induced murine candidiasis.
26 *Microbiology and Immunology*, 28, 903-912.
- 27 Swatschek, D., Schatton, W., Kellerman, J., Muller, W.E.G. & Kreuter, J. (2002).
28 Marine Sponge Collagen: Isolation, Characterization and Effects on the Skin
29 Parameters Surface pH, Moisture and Sebum. *European Journal of*
30 *Pharmaceutics and Biopharmaceutics*, 53, 107-113.
- 31 Takahashi, Y., Itami, T., Kajiwaki, T. (1992). Bacteriolytic substances in the skin
32 mucus of yellowtail. *Gyobyō Kenkyū*, 27, 171-172.
- 33 Takeshi, N., & Suzuki, N. (2000). Isolation of collagen from fish waste material-
34 skin, bone and fins. *Food Chemistry*, 68, 277-281.
- 35 Tsai, G., & Hwang, S. (2004). In vitro and in vivo antibacterial activity of shrimp
36 chitosan against some intestinal bacteria. *Fisheries science*, 70, 675-681.

1 Tsai, G.J., Su, W.H. (1999) Antibacterial activity of shrimp chitosan against
2 *Escherichia coli*. *Journal of food protection*, 62, 239-243.

3 Uresti, R.M., Téllez-Luis, S.J., Ramírez, J.A., vazquez, M. (2004). Use of dairy
4 proteins and microbial transglutaminase to obtain low-salt fish products from
5 filleting waste from silver carp (*Hypophthalmichthys molitrix*). *Food chemistry*,
6 86, 257-262.

7 Vannuccini, S. (2004). Overview of fish production, utilization, consumption and
8 trade. FAO fishery information, data and statistic unit report.

9 Vazquez, J.A., Gonzalez, M.P. and Murado, M.A. (2004) Peptones from
10 autohydrolysed fish viscera for nisin and pediocin production. *Journal of*
11 *biotechnology*, 112,299–311.

12 Vidotti, R.M, Viegas, E.M.M., Carneiro, D.J. (2003). Aminoacid composition of
13 processed fish silages using different raw materials. *Animal feed science and*
14 *technology*, 105, 199-204.

15 Ward, A.G., & Courts, A. (1977). The science and technology of gelatine.
16 London: Academic Press.

17 Watson, R. & Pauly D. (2001). Systematic distortions in world fisheries catches
18 trends. *Nature*, 414, 534-536.

19 Zhou P & Regenstein JM.(2005). Effects of Alkaline and Acid Pretreatments on
20 Alaska Pollock Skin Gelatin Extraction. *Journal of Food Science*, 70(6), 392-
21 396.

22

23

24

25

26

27